Volume 24 MAY, 1940 Number 5

BULLETIN
of the
American Association of Petroleum Geologists

CONTENTS

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICE OF PUBLICATION, 608 WRIGHT BUILDING, TULSA, OKLAHOMA

THE BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS is published by the Association on the 15th of each month. Editorial and publication office, 608 Wright Building, Tulsa, Oklahoma. Post Office Box 979. Cable address, AAPGEOL.

THE SUBSCRIPTION PRICE to non-members of the Association is $15.00 per year (separate numbers, $1.50) prepaid to addresses in the United States. For addresses outside the United States, an additional charge of $0.40 is made on each subscription to cover extra wrapping and handling.

British agent: Thomas Murby & Co., 1 Fleet Lane, Ludgate Circus, London, E. C. 4.

CLAIMS FOR NON-RECEIPT of preceding numbers of THE BULLETIN must be sent Association headquarters within three months of the date of publication in order to be filled gratis.

BACK NUMBERS OF THE BULLETIN, as available, can be ordered from Association headquarters. Cloth-bound Vols. 11 (1927) to 15 (1931), Vols. 22 (1938) to 23 (1939), each $17.00. Other volumes, many separate numbers, and a few nearly complete sets are available. Descriptive price list sent on request. Special prices to members and associates. Discounts to libraries. *Geology of Natural Gas* (1935), $6.00 ($4.50 to members and associates). *Geology of Tampico Region, Mexico* (1936), $4.50 ($3.50 to members and associates). *Structural Evolution of Southern California* (1936), $2.00. *Gulf Coast Oil Fields* (1936), $4.00 ($3.00 to members and associates). *Comprehensive Index, 1917-1936* (1937), $3.00 (to members and associates: free; extra copy, $2.00). *Miocene Stratigraphy of California* (1938), $5.00 ($4.50 to members and associates). *Recent Marine Sediments* (1939), $5.00 ($4.00 to members and associates).

THE BULLETIN gives senior authors 35 reprints of major papers. Additional reprints, in limited numbers, and for private distribution, are furnished at cost, if orders accompany corrected galley proof.

Association Headquarters—608 Wright Building, 115 and 117 West Third Street, Tulsa, Oklahoma.

Communications about the Bulletin, manuscripts, editorial matters, subscriptions, special rates to public and university libraries, publications, membership, change of address, advertising rates, and other Association business should be addressed to

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

BOX 979
TULSA, OKLAHOMA

Entered as second-class matter at the Post Office at Tulsa, Oklahoma, and at the Post Office at Menasha, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

Organized at Tulsa, Oklahoma, February 10, 1917, as the Southwestern Association of Petroleum Geologists. Present name adopted, February 16, 1918. Incorporated in Colorado, April 23, 1924. Domesticated in Oklahoma, February 9, 1925.)

OFFICERS FOR THE YEAR ENDING MARCH, 1941

L. C. SNIDER, *President*, New York City
JOHN M. VETTER, *Vice-President*, Houston, Texas
EDGAR W. OWEN, *Secretary-Treasurer*, San Antonio, Texas
WALTER A. VER WIEBE, *Editor*, Wichita, Kansas

The foregoing officers, together with the *Past-President*, HENRY A. LEY, San Antonio, Texas, constitute the Executive Committee.

DISTRICT REPRESENTATIVES

(Representatives terms expire immediately after annual meetings of the years shown in parentheses)

Amarillo: C. Don Hughes (42), Amarillo, Tex.
Appalachian: Paul H. Price (41), Morgantown, W. Va.
Canada: S. E. Slipper (41), Calgary, Canada
Capital: L. W. Stephenson (42), Washington, D. C.
Dallas: W. W. Clawson (42), Dallas, Tex.
East Oklahoma: N. W. Bass (41), Robert H. Wood (41), Tulsa, T. E. Weirich (42), Bartlesville
Fort Worth: Charles E. Yager (41), Fort Worth, Tex.
Great Lakes: William Norval Ballard (41), Holland, Mich.; A. H. Bell (41), Urbana, Ill.
Houston: J. Boyd Best (41), Lon D. Cartwright, Jr. (41), R. L. Beckelhymer (42), Houston, Tex.
New Mexico: Delmar R. Guinn (41), Hobbs, N. Mex.
New York: W. T. Thom, Jr. (41), Princeton, N. J.
Pacific Coast: Harold K. Armstrong (14), Herschel L. Driver (41), E. C. Edwards (42), Los Angeles, Calif.
Rocky Mountains: C. E. Dobbin (41), Denver, Colo.
Shreveport: C. L. Moody (41), Shreveport, La.
South America: Roger H. Sherman (41), Caripito, Venezuela
Southeast Gulf: James H. McGuirt (41), University, La.
So. Permian Basin: Ronald K. De Ford (41), Midland, Tex.
South Texas: C. C. Miller (41), Corpus Christi; Harry H. Nowlan (41), San Antonio, Tex.
Tyler: Edward B. Wilson (41), Tyler, Tex.
West Oklahoma: C. W. Tomlinson (41), Ardmore, Okla.
Wichita: James I. Daniels (41), Wichita, Kan.
Wichita Falls: James F. Gibbs (42), Wichita Falls, Tex.

DIVISION REPRESENTATIVES

Paleontology and Mineralogy

Carey Croneis (41), Chicago, Illinois
Henryk B. Stenzel (41), Austin, Texas

PACIFIC SECTION (Chartered, March, 1925)

ALBERT GREGERSEN, *President*, The Texas Company, Los Angeles, California
E. J. BARTOSH, *Secretary-Treasurer*, Bankline Oil Company, Los Angeles, California
Membership restricted to members of the Association in good standing, residing in Pacific Coast states. Dues: $1.50 per yea

---

SOUTH TEXAS SECTION (Chartered, April, 1929)

FRED P. SHAYES, *President*, United Gas Company, Beeville, Texas
ROBERT N. KOLM, *Secretary-Treasurer*, 1742 Milam Building, San Antonio, Texas
Membership limited to persons eligible to Association membership. Dues: $2.50. Annual meeting in October.

MARACAIBO SECTION (Chartered, April, 1930)

JOHN G. DOUGLAS, *President*, Mene Grande Oil Company, Apartado 234, Maracaibo, Venezuela

---

DIVISION OF PALEONTOLOGY AND MINERALOGY
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(Organized, March, 1927; affiliated, March, 1928; chartered, technical division, April, 1930)
CAREY CRONEIS, *President*, Chicago, Illinois
HENRYK B. STENZEL, *Secretary-Treasurer*, Bureau of Economic Geology, Austin, Texas
SEND DUES, SUBSCRIPTIONS, AND ORDERS FOR BACK NUMBERS TO BOX 979, TULSA, OKLAHOMA.
The Society and the Paleontological Society jointly issue six times a year the *Journal of Paleontology*, Norman D. Newell, University of Wisconsin, Madison, Wisconsin, and C. Wythe Cooke, U. S. Geological Survey, Washington, D. C., editors: subscription, $6.00. The *Journal of Sedimentary Petrology*, W. H. Twenhofel, editor, University of Wisconsin, Madison, Wisconsin, is issued three times a year: subscription, $3.00. Single copies, *Journal of Paleontology*, $2.00; *Journal of Sedimentary Petrology*, $1.50. Society dues: with *Jour. Pal.*, $6.00; with *Jour. Sed. Petrology*, $3.00; with both, $8.00 per year.

AFFILIATED SOCIETIES

(Dates of affiliation in parentheses)

Alberta Society of Petroleum Geologists, Calgary, Alberta, Canada (31). R. G. Paterson, Secy., 215 Sixth Avenue, West
Appalachian Geological Society, Charleston, W. Virginia (31). Thurman H. Myers, Secy., Carnegie Natural Gas Co., Pittsburgh, Pa.
Ardmore Geological Society, Ardmore, Oklahoma (36). Tom L. Coleman, Secy., U. S. Geological Survey
Dallas Petroleum Geologists, Dallas, Texas (35) D. M. Collingwood, Secy., Sun Oil Company
East Texas Geological Society, Tyler, Texas (32). C. I. Alexander, Secy., Magnolia Petroleum Company
Fort Worth Geological Society, Fort Worth, Texas (31). Vernon Lipscomb, Secy., The Pure Oil Company
Houston Geological Society, Houston, Texas (32). Olin G. Bell, Secy., Humble Oil and Refining Company
Illinois Geological Society (39). James G. Mitchell, Secy., Pure Oil Company, Clay City
Indiana-Kentucky Geological Society (38). Stanley G. Elder, Secy., Sun Oil Company, Evansville, Indiana
Kansas Geological Society, Wichita, Kansas (31). Lee H. Cornell, Secy., Stanolind Oil and Gas Company
Michigan Geological Society (37). C. H. Riggs, Secy., Michigan Geological Survey Division, Grand Rapids
North Texas Geological Society, Wichita Falls, Texas (38). R. E. McPhail, Secy., Phillips Petroleum Company
Oklahoma City Geological Society, Oklahoma City, Oklahoma (31). F. Mabry Hoover, Secy., Cities Service Oil Company
Panhandle Geological Society, Amarillo, Texas (32). H. H. Hinson, Secy., U. S. Bureau of Mines, Box 2250
Shawnee Geological Society, Shawnee, Oklahoma (31). F. Spencer Withers, Secy., Atlantic Refining Company
Shreveport Geological Society, Shreveport, Louisiana (32). Weldon E. Cartwright, Secy., Tide Water Associated Oil Company
Society of Exploration Geophysicists, Tulsa, Okla. (32). Andrew Gilmour, Secy., Amerada Petroleum Corporation
South Louisiana Geological Society, Lake Charles, La. (37). Baker Hoskins, Secy., Shell Oil Company, Inc.
Southwestern Geological Society, Austin, Texas (37). S. A. Lynch, Secy., Department of Geology, University of Texas
Tulsa Geological Society, Tulsa, Oklahoma (31). Louis H. Lukert, Secy., The Texas Company, Box 2420
West Texas Geological Society, Midland, Texas (38). Fred F. Kotyza, Secy., Tide Water Associated Oil Company

Bulletin Advertisers

PROFESSIONAL CARDS

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

Articles for June *Bulletin*

Wildcat Drilling in 1939
By Frederic H. Lahee

Developments in Eastern Interior Basin, 1939-1940
By Alfred H. Bell

Deep Sand Developments, Appalachian Region, 1939
By Thurman H. Myers

Developments in Michigan during 1939
By R. B. Newcombe

Recent Developments in North Mid-Continent
By Edward A. Koester

Revent Developments in Oklahoma
By E. F. Shea

Recent Developments in South Mid-Continent
By Lewis W. MacNaughton

Developments in New Mexico and West Texas
By Dana Secor

Developments in North and West-Central Texas
By Karl A. Mygdal

Developments in East Texas
By E. A. Wendlandt and H. J. McClellan

Developments and Oil Reserves in South Texas
By L. B. Herring

Review of Developments in 1939, Gulf Coast of Upper Texas and Louisiana
By O. L. Brace

Developments in Arkansas and Louisiana
By W. B. Weeks and Joseph Purzer

Developments in Mississippi
By H. N. Toler

Developments in Rocky Mountain Region in 1939
By C. E. Dobbin

Significant Developments in California, 1939
By E. Robert Atwill

Volume 24 Number 5

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

MAY, 1940

MISSISSIPPIAN BORDER OF EASTERN INTERIOR BASIN[1]

J. MARVIN WELLER[2] AND A. H. SUTTON[3]
Urbana, Illinois

ABSTRACT

The Mississippian system along the borders of the Eastern Interior basin has been studied in considerable detail during the last 30 years but the results of most of this work have not yet been published. This paper briefly discusses the stratigraphy, paleontology, sedimentation, and structure and lists petroleum-bearing beds of the Mississippian system in Illinois, Indiana, western Kentucky, eastern Missouri, and southeastern Iowa as based on the published and unpublished investigations of more than 25 geologists and their numerous assistants, who worked mainly under the auspices of the various State geological surveys. Accompanying maps show the areal geology from Mercer County, Illinois, to Putnam County, Indiana, and include more than fifty 15-minute quadrangles which have been studied in detail.

INTRODUCTION

In 1913 a coöperative plan of study and correlation of the Mississippian formations of the upper Mississippi Valley was developed by the several State geological surveys of the area and the United States Geological Survey. This work was placed under the supervision of Professor Stuart Weller, who had been actively engaged in a study of the Mississippian faunas for more than 15 years and who had begun the detailed mapping of the upper Mississippian strata in southern Illinois in 1911.

As results of this coöperative investigation there have appeared two important volumes on the lower Mississippian of Iowa and Missouri, respectively (67, 41).[4] Other volumes on the Mississippian formations of western Kentucky (7) and the lower Mississippian of

[1] Read before the Association at Oklahoma City, March 24, 1939. Manuscript received, October 2, 1939. Published by permission of the chief, Illinois State Geological Survey; the director, Kentucky Geological Survey; the State geologist of Indiana; and the director, Missouri Geological Survey.

[2] Illinois State Geological Survey.

[3] University of Illinois.

[4] Numbers in parentheses refer to bibliography at end of article.

System	Series	Group	Standard Section	SW Illinois	SE Ill. & W Ky.	W Central Ky	SW Indiana
Mississippian System	Chester Series	Elvira Group	KINKAID LS.	KINKAID LS	KINKAID LS.	LEITCHFIELD FM.	NEGLI CREEK LS
			DEGONIA SS	DEGONIA SS.	DEGONIA SS.		MT. PLEASANT SS.
			CLORE SH & LS	CLORE SH & LS	CLORE SH. & LS.		GENNET CREEK SH.
			PALESTINE SS	PALESTINE SS	PALESTINE SS		BRISTOW SS.
			MENARD LS	MENARD LS	MENARD LS		SIBERIA LS.
			WALTERSBURG SS	BALDWIN FM.	WALTERSBURG SS.		WICKCLIFF SS.
			VIENNA LS.		VIENNA LS.		UNNAMED SH.
			TAR SPRINGS SS.		TAR SPRINGS SS.		TAR SPRINGS SS.
		Homberg Group	GLEN DEAN LS	OKAW LS.	GLEN DEAN LS	GLEN DEAN LS	GLEN DEAN LS.
			HARDINSBURG SS		HARDINSBURG SS	HARDINSBURG SS.	HARDINSBURG SS.
			GOLCONDA LS.		GOLCONDA SH & LS	GOLCONDA LS	GOLCONDA LS.
							INDIAN CREEK SH.
			CYPRESS SS	RUMA FM.	CYPRESS SS	CYPRESS SS.	CYPRESS SS.
		New Design Group	PAINT CREEK SH & LS	PAINT CREEK SH.	PAINT CREEK SH & LS.	GIRKIN LS	BEECH CREEK LS.
							ELWREN SS.
							REELSVILLE LS
			BETHEL SS.	YANKEETOWN CHERT	BETHEL SS.		SAMPLE SS
			RENAULT LS & SH.	RENAULT FM.	RENAULT LS. & SH.		BEAVER BEND LS
							MOORETOWN LS
							PAOLI LS
			AUX VASES SS.	AUX VASES SS			
	Iowa Series	Meramec Group	STE. GENEVIEVE LS.	HOFFNER MEMBER			
				LEVIAS LS.	LEVIAS LS.	STE. GENEVIEVE LS.	STE GENEVIEVE LS.
				ROSICLARE SS.	ROSICLARE SS		
				FREDONIA LS	FREDONIA LS.		
			ST LOUIS LS.	ST. LOUIS LS	ST LOUIS LS.	ST. LOUIS LS	ST LOUIS LS
			SALEM LS.	SALEM LS.	WARSAW LS.	WARSAW LS.	SALEM LS
		Osage Group	WARSAW FM.	WARSAW LS.			HARRODSBURG LS
			KEOKUK LS.	OSAGE FM.	OSAGE FM.	EDWARDSVILLE FM.	EDWARDSVILLE FM.
			BURLINGTON LS.			CARWOOD FM.	CARWOOD FM.
			FERN GLEN LS. & SH.			LOCUST POINT FM.	LOCUST POINT FM.
						NEW PROVIDENCE SH	NEW PROVIDENCE SH.
		Kinderhook Group	CHOUTEAU LS				ROCKFORD LS
			HANNIBAL SH & SS.	SPRINGVILLE SH			
			LOUISIANA LS				
			GRASSY-SAVERTON SH.				
				MOUNTAIN GLEN SH	CHATTANOOGA SH. PART	NEW ALBANY SH. PART	NEW ALBANY SH PART

FIG. 1.—Correlation chart of Mississippian formations exposed on borders of Eastern Interior basin. Ls., limestone; ss., sandstone; sh., shale; fm., formation.

Missouri (4) have also been published, but these were not a part of the coöperative program. All of these reports were based on reconnaissance studies.

Professor Weller's own investigations, which continued without interruption until his death in 1927, as well as the work of others under his supervision, involved the detailed mapping of the Mississippian formations in southwestern Missouri, across southern Illinois, and well into western Kentucky. Although reports on detailed studies in certain restricted areas have been issued (32, 56, 68, 87, 88, 90, 94, 96), publication of the results of most of this work was deferred in anticipation of a series of monographs long planned by Professor Weller but hardly begun before his death.

After 1927, Mississippian studies in western Kentucky were continued under the direction of Sutton, and by 1932 mapping of the formations was nearly completed throughout the zone of outcrop from St. Louis, Missouri, to Louisville, Kentucky.

In western Illinois north of St. Louis, detailed studies of the Mississippian system have been made in connection with a number of separate quadrangle surveys, but the deep covering of glacial drift and uncertainty regarding the exact position of several formational boundaries make it impossible as yet to delineate accurately the areal geology throughout this region.

The belt of Mississippian outcrop in southwestern Indiana has been studied mainly in reconnaissance because of the lack of topographic maps, but the recent work of C. A. Malott and P. B. Stockdale has added much to the knowledge of this region.

As detailed information concerning the Mississippian system and particularly its upper division, the Chester series, has accumulated, a growing need has been felt for a report or series of reports describing its stratigraphy and structure. This paper is presented as a preliminary report outlining in a unified manner the latest and most complete information available concerning the Mississippian system on the borders of the Eastern Interior basin. It embodies data obtained by more than twenty-five geologists and their numerous assistants working mainly under the auspices of the various State geological surveys. Permission to use much unpublished information and many manuscript maps has been granted by the chief of the Illinois State Geological Survey, the director of the Kentucky Geological Survey, the State geologist of Indiana, and the director of the Missouri Bureau of Geology and Mines.

Professor Weller's extensive and detailed studies, with which the writers are intimately acquainted, have provided the foundation of

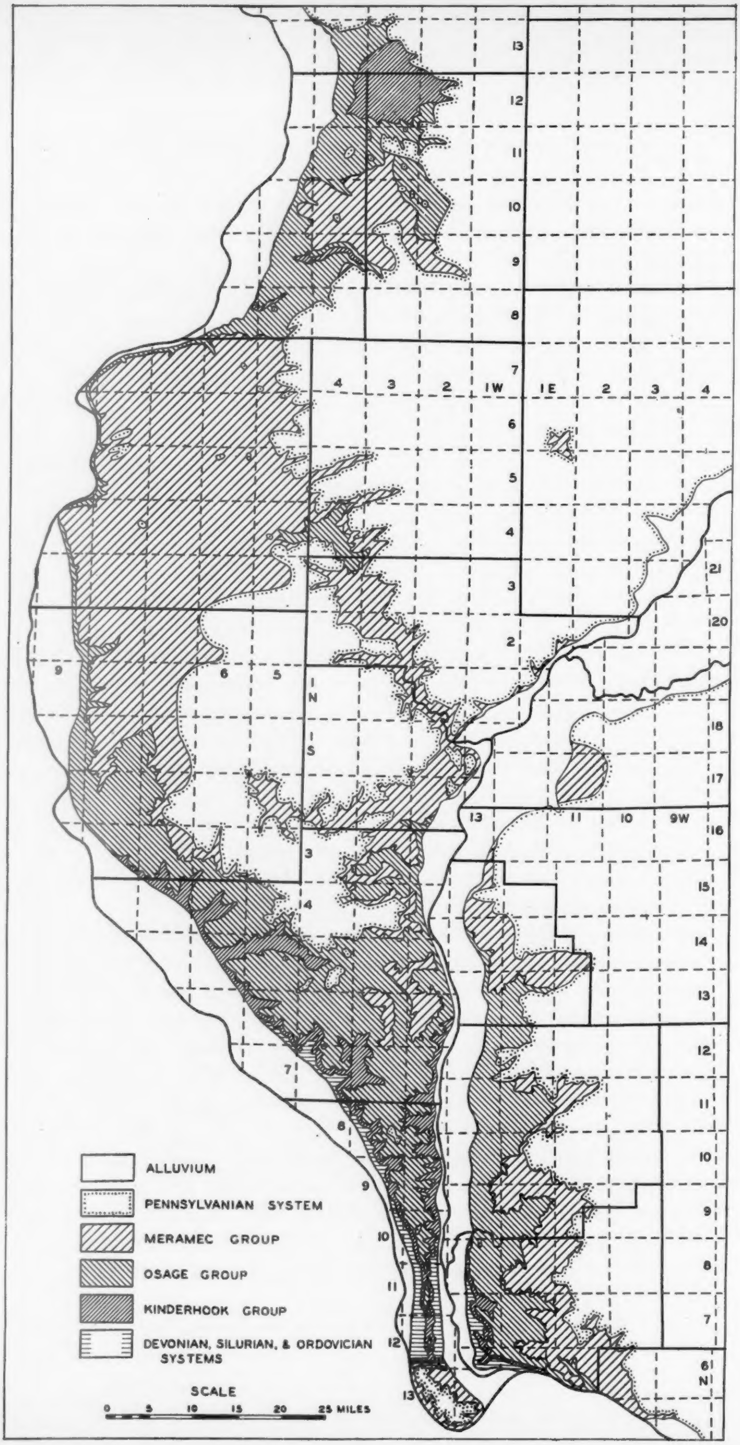


FIG. 2.—Map showing distribution of outcropping Mississippian rocks in western Illinois from Madison County to Mercer County. (After "Geologic Map of Illinois," compiled by J. Marvin Weller with assistance of other members of Survey staff, *Illinois State Geological Survey*, July 1, 1939.)

the following stratigraphic and paleontologic discussions and much of the information contained therein. C. A. Malott has generously placed at the writers' disposal unpublished information concerning the Chester series in Indiana. Others whose unpublished work in Illinois and Kentucky has contributed to the completeness of this paper are: A. H. Bell, C. C. Branson, B. B. Cox, J. A. Culbertson, George E. Ekblaw, R. F. Flint, J. R. Griffin, F. F. Krey, S. M. Mayfield, W. W. Ruby, T. E. Savage, A. H. Sutton, J. R. VanPelt, Jr., and J. M. Weller.

The map showing the distribution of the Mississippian rocks in western Illinois (Fig. 2) is copied from a new geological map of Illinois compiled by J. M. Weller.

The areal maps (Figs. 4–9b) accompanying this paper are copied from geological maps prepared by various men on standard quadrangle topographic maps (scale, 1 inch equals 1 mile) on most of which each formation is indicated separately. Reduction in scale, however, has made it necessary to combine the different formations into (1) upper Chester, (2) middle Chester, (3) lower Chester, (4) Meramec, and (5) Osage groups. The Kinderhook group is not shown because it is either absent or too thin, or because it is not differentiated from the "Devonian" black shale.

An unpublished generalized map of the three main divisions of the Chester series in Indiana, as prepared by C. A. Malott, has been used in combination with the geological map of the state to produce the areal map of the same Mississippian groups in Indiana (Fig. 10).

EASTERN INTERIOR BASIN

The Eastern Interior basin is an irregularly subcircular structural depression 250 to 300 miles in diameter, occupying the greater part of Illinois, southwestern Indiana, and western Kentucky and attaining in southeastern Illinois a maximum structural depth of more than 5,000 feet below its borders. It is bounded on the northeast by the Kankakee arch, on the east by the Lexington dome, on the southeast by the Nashville dome, on the south by the Mississippi embayment. on the southwest by the Ozark dome, and on the northwest by the Mississippi arch. The structure of this arch, which separates the Eastern Interior and Western Interior basins, is not known in detail. It appears to be a broad, more or less irregular saddle connecting the northeastern extremity of the Ozark uplift with the southwestern slope of the Wisconsin arch. Its axis is probably located farther west and trends more nearly northeast and southwest than is shown on

recent maps.[5] The Mississippi arch is evidently a very old structure which influenced sedimentation at least from the Ordovician through Pennsylvanian time, as many formations thin notably upon it.

The major structural features within the Eastern Interior basin are the asymmetrical LaSalle anticline which extends southeastward across Illinois from near Dixon to Wabash River; the Shawneetown-Rough Creek zone of faulting which extends from Saline County, Illinois, to Hart County, Kentucky; the complicated fault zone that extends from Union County, Illinois, to Ste. Genevieve County, Missouri; the Hicks dome in Hardin County, Illinois, and the associated faulted area in neighboring parts of Illinois and Kentucky; the Valmeyer anticline in Monroe County, Illinois, and Jefferson County, Missouri; the Waterloo-Dupo anticline in Monroe and St. Clair counties, Illinois, and St. Louis County, Missouri; the Cap-au-Gres fault and flexure zone which extends from Jersey County, Illinois, through Lincoln County, Missouri; the Pittsfield anticline in Pike County, Illinois; the Lincoln anticline in Lincoln and Pike counties, Missouri; and the Du Quoin "anticline" in southwestern Illinois. Minor faults and folds are common elsewhere in the basin.

Throughout at least the latter part of the Paleozoic era the Eastern Interior basin was a dominantly negative area whose form was determined by the passively positive Ozark dome, Wisconsin and Lake Superior highlands, and Cincinnati arch. The western, northern, and eastern limits of the basin were determined long before the beginning of the Mississippian period, but the southern border was produced by post-Paleozoic pre-late Cretaceous deformation.

MISSISSIPPIAN SYSTEM

General distribution.—The Mississippian system underlies approximately 70,000 square miles in Illinois, Indiana, and western Kentucky and crops out in a belt 750 miles long around the western, southern and eastern borders of the Eastern Interior basin. It attains a maximum thickness of nearly 3,000 feet in southern Illinois and western Kentucky and thins northward because in that direction not only do its constituent formations thin but they are also bevelled by post-Mississippian pre-Pennsylvanian erosion.

Economic importance.—Nearly half of the petroleum produced from the old fields in this region and most of that produced from the new Illinois fields have come from Mississippian formations. The limestone strata are used extensively for lime, crushed rock, riprap, rock

[5] See J. V. Howell, "Tectonic Map of Central United States," *Kansas Geological Society* (1931), and "The Mississippi River Arch," *Kansas Geological Society, Ninth Annual Field Conference Guide-Book* (1935), pp. 386–89.

wool, and similar products, and certain strata are quarried for dimension stone in the Bedford, Indiana, district which is the greatest center of the building-stone industry in the United States. The fluorspar in the famous southern Illinois and western Kentucky district and some of the natural rock asphalt in west-central Kentucky occur in Mississippian rocks.

Classification.—A relatively recent discussion of the classification of the Mississippian strata in the upper Mississippi and lower Ohio valleys has already been published (16, pp. 475–86). The classification which has been standard in the most recent publications of the Illinois State Geological Survey is used in this report and accordingly the Mississippian system is subdivided into the Iowa series below, consisting of the Kinderhook, Osage, and Meramec groups, and the Chester series above.

For several years, however, the writers have believed that the stratigraphic and faunal relations existing within the Mississippian system are more in accord with a three-fold subdivision and that the Kinderhook should be raised in rank from a group to a series and that another, the Valmeyer series,[6] consisting of the Osage and Meramec groups, should be recognized. The system would thus be separated into beds of lower, middle, and upper Mississippian age in a manner similar to most of the other Paleozoic systems. The reasons follow.

1. A careful consideration of the successive Mississippian faunas shows that, although the Chester and Iowa series consist of approximately equal thicknesses of strata, the Iowa contains the record of a much greater life development and so presumably represents much the greater part of Mississippian time. A considerable array of invertebrate species range from the bottom to the top of the Chester series but only a single rather elastic species, *Linoproductus ovatus*, passes from the Kinderhook through the Osage and into the Meramec group.

2. The Chester series with its preponderantly clastic strata is in strong contrast to the Osage and Meramec groups in the type area where they are represented largely by limestone, and on this basis the

[6] This three-fold division of the Mississippian system and the name Valmeyer, from a town in southwestern Illinois, were first proposed by the writers in a manuscript on the Mississippian formations of the Eastern Interior basin written in 1930–31. Shortly afterward, R. C. Moore submitted for their comment part of the manuscript for a textbook in which he was also proposing an identical division. After consultation, Moore accepted the name Valmeyer for the middle series and this was first published in his book (42, pp. 261–64). This classification has been used in a number of subsequent publications but objections to it have been expressed (34, pp. 1158–59). Recently Moore has abandoned this classification in favor of another three-fold classification consisting in ascending order of the Waverly, Meramec, and Chester series (44, p. 671), but the writers believe that this subdivision is not in harmony with the stratigraphic and faunal characters of the Mississippian system in the central United States.

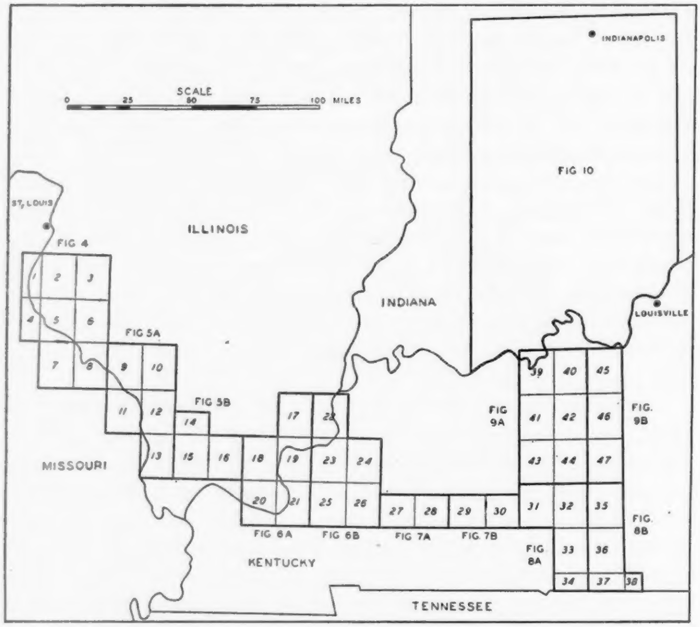


FIG. 3.—Index map showing areas covered in Figs. 4–10. Numbers within quadrangles serve as index to following list of names, wherewith are also given names of geologists who mapped Mississippian strata, dates of mapping, and character of mapping (detail, semi-detail, and reconnaissance). Asterisk (*) indicates unpublished maps.

(1) *Kimmswick Quadrangle* (Illinois portion), Stuart Weller, 1911, detail
(2) *Waterloo Quadrangle*, Stuart Weller, 1911, detail
(3) *New Athens Quadrangle*, Stuart Weller, detail
(4) *Crystal City Quadrangle* (Illinois portion), Stuart Weller, 1913, detail
(Ste. Genevieve County, Missouri portion), Stuart Weller, 1914, detail
(5) *Renault Quadrangle* (Illinois portion), Stuart Weller, 1912, detail
(Missouri portion), Stuart Weller, 1914, detail
(6) *Baldwin Quadrangle*, Stuart Weller, 1913, detail
(7) *Weingarten Quadrangle*, Stuart Weller, 1914, detail
(8) *Chester Quadrangle* (Illinois portion), Stuart Weller, 1913, detail
(Missouri portion), Stuart Weller, 1914, detail
(9) *Campbell Hill Quadrangle*, J. M. Weller, 1919, detail
(10) *Murphysboro Quadrangle*, E. W. Shaw, 1909, semi-detail
(11) *Altenburg Quadrangle* (Missouri portion), R. F. Flint, 1924, detail*
(12) *Alto Pass Quadrangle*, F. F. Krey, 1923, G. E. Ekblaw, 1924, detail* (incomplete)
(13) *Jonesboro Quadrangle*, T. E. Savage, 1919, detail*
(14) *Carbondale Quadrangle*, J. E. Lamar, 1922, 1923, detail
(15) *Dongola Quadrangle*, F. F. Krey, 1921, detail
(16) *Vienna Quadrangle*, Stuart Weller, 1918, 1919, detail
(17) *Equality Quadrangle*, Charles Butts, 1917, 1918, detail
(18) *Brownsfield Quadrangle*, Stuart Weller, 1916, 1917, 1918, 1924, detail

(19) *Golconda Quadrangle* (Illinois portion), Stuart Weller, 1917, detail
(Kentucky portion), Stuart Weller, 1920, detail*
(20) *Paducah Quadrangle*, Stuart Weller, 1926, detail*
(21) *Smithland Quadrangle* (Illinois portion), Stuart Weller, 1926, detail*
(Kentucky portion), Stuart Weller, 1927; A. H. Sutton, 1927, 1928, 1929, detail*
(22) *Shawneetown Quadrangle* (Illinois portion), W. T. Lee, 1915; Charles Butts, 1917, 1918, detail
(23) *Cave in Rock Quadrangle* (Illinois portion), Stuart Weller, 1917, detail
(Kentucky portion), Stuart Weller, 1922, 1923, 1926, detail*
(24) *Providence Quadrangle* (Caldwell County portion), A. H. Sutton, 1928, semi-detail*
(25) *Eddyville Quadrangle*, A. H. Sutton, 1928, 1929, detail*
(26) *Princeton Quadrangle*, Stuart Weller, 1921, detail*
(27) *Dawson Springs Quadrangle*, A. H. Sutton, 1926, detail*
(28) *Nortonville Quadrangle*, A. H. Sutton, 1927, 1929, detail*
(29) *Drakesboro Quadrangle* (Muhlenburg County portion), J. G. Woodruff, 1929, semi-detail
(Todd and Logan County portions), A. H. Sutton, 1930, detail
(30) *Dunmor Quadrangle* (Muhlenburg County portion), J. G. Woodruff, 1929, semi-detail
(Butler County portion), A. C. McFarlan, 1928, detail
(Logan County portion), A. H. Sutton, 1931, detail
(31) *Little Muddy Quadrangle* (Butler County portion), A. C. McFarlan, 1928, detail
(Warren County portion), R. F. Flint, 1925, reconnaissance
(Logan and Warren County portions), A. H. Sutton, 1931, detail
(32) *Brownsville Quadrangle* (Warren County portion), J. M. Weller, 1924, J. A. Culbertson and J. R. Griffin, 1929, detail*
(Edmonson County portion), J. M. Weller, 1924, detail
(33) *Bowling Green Quadrangle* (Warren County portion), R. F. Flint, 1925, reconnaissance
(Allen County portion), A. H. Sutton, 1930, detail*
(34) *Adolphus Quadrangle* (Allen County, Kentucky portion), A. H. Sutton, 1930, detail*
(35) *Mammoth Cave Quadrangle* (Edmonson County portion), J. M. Weller, 1924, detail
(Warren and Barren counties portion), Charles Butts, 1919, and R. F. Flint, 1925, reconnaissance
(36) *Scottsville Quadrangle* (Warren and Barren counties portion), Charles Butts, 1919, and R. F. Flint, 1925, reconnaissance
(Allen County portion), A. H. Sutton, 1930, detail*
(37) *Lafayette Quadrangle* (Kentucky portion), A. H. Sutton, 1930, detail*
(38) *Red Boiling Springs Quadrangle* (Allen County, Kentucky portion), A. H. Sutton 1930, detail*
(39) *Cannelton Quadrangle* (Ohio County portion), S. M. Mayfield, 1930, detail*
(Breckenridge County portion), J. A. Culbertson and J. R. Griffin, 1930, semi-detail*
(40) *Hardinsburg Quadrangle*, J. R. Griffin, 1929, semi-detail*
(41) *Falls of Rough Quadrangle*, S. M. Mayfield, 1930, detail*
(42) *Kirk Quadrangle* (not mapped topographically) (Breckenridge County portion), J. A. Culbertson and J. R. Griffin, 1930, semi-detail*
(Grayson County portion), J. M. Weller and A. H. Sutton, 1925, reconnaissance
(43) *Spring Lick Quadrangle*, J. A. Culbertson and J. R. Griffin, 1929, reconnaissance
(44) *Leitchfield Quadrangle* (Grayson County portion), J. A. Culbertson and J. R. Griffin, 1929, reconnaissance*
(Edmonson County portion), J. M. Weller, 1924, detail
(45) ——— *Quadrangle* (not mapped topographically) (Meade County portion), A. H. Sutton and O. E. Wagner, 1930, reconnaissance
(Breckenridge County portion), J. A. Culbertson and J. R. Griffin, 1930, semi-detail*
(Hardin County portion), J. M. Weller and A. H. Sutton, 1925, reconnaissance
(46) *Big Clifty Quadrangle*, J. A. Culbertson, 1929, semi-detail*
(47) *Cub Run Quadrangle* (Edmonson County portion), J. M. Weller, 1924, detail
(remainder of quadrangle), A. H. Sutton, 1927, reconnaissance

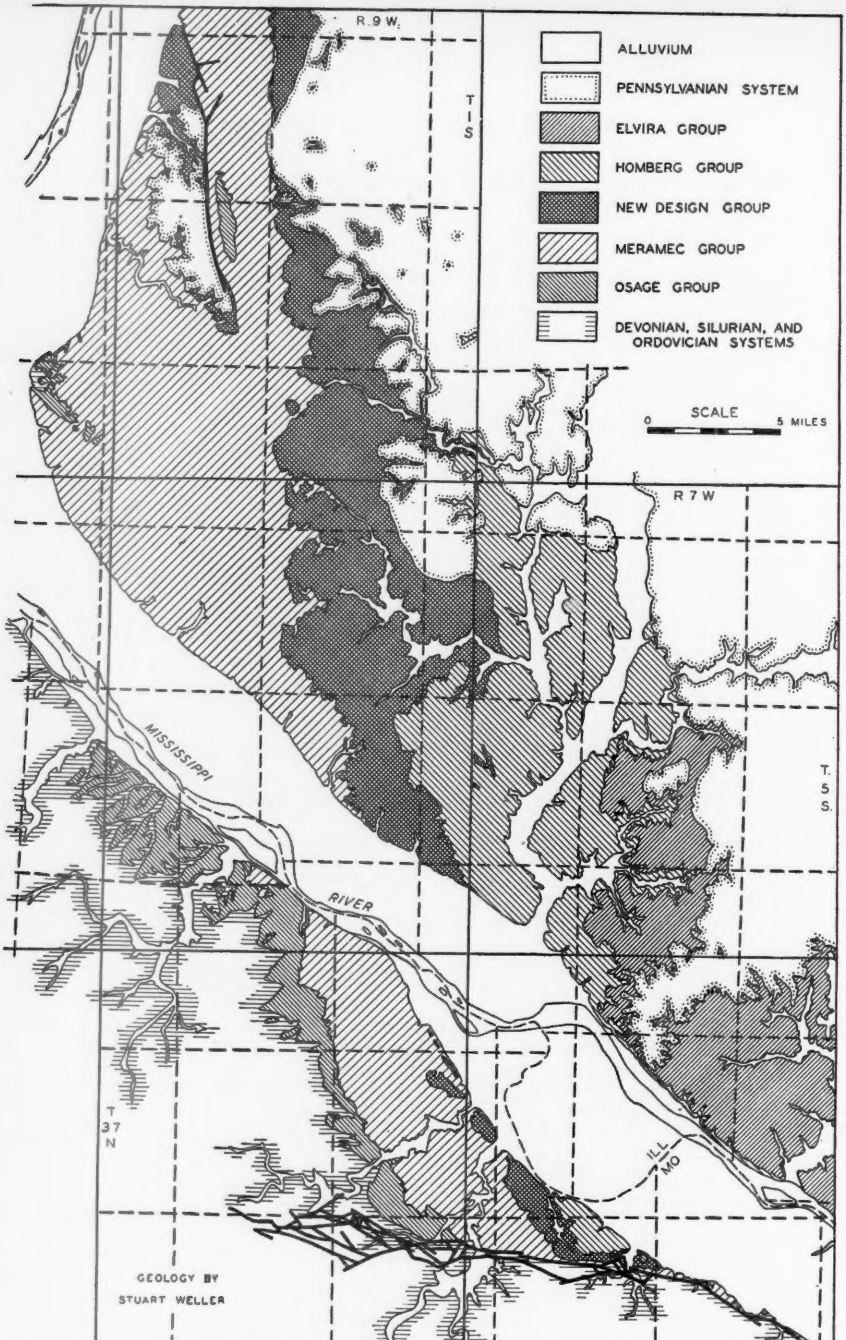


FIG. 4.—Areal geologic map of parts or all of following quadrangles: Kimmswick, Waterloo, New Athens, Crystal City, Renault, Baldwin, Weingarten, Chester. See index map (Fig. 3). Geologic mapping under auspices of Illinois State Geological Survey and Missouri Geological Survey.

Chester may be assumed to have accumulated much more rapidly. It seems logical, therefore, to consider that the Chester, in spite of its much greater thickness, represents an interval of time more nearly comparable to that of each of the two proposed lower divisions.

3. What appear to be the two most important unconformities in the Mississippian system in its type area occur (a) between the Kinderhook and Osage groups and (b) between the Meramec group and Chester series.

4. With this arrangement the most typical and earliest studied Mississippian faunas fall within the middle division. The Kinderhook or lowermost division contains faunas whose molluscan elements are strongly suggestive of the Devonian, and the uppermost division, the Chester series, contains faunas whose molluscan portion characteristically has strong Pennsylvanian affinities.

BASAL STRATIGRAPHIC RELATIONS

The relations of the Mississippian and Devonian systems in the central United States are confused because throughout large areas a thick shale formation, commonly black and generally barren of diagnostic fossils, lies between strata containing respectively Devonian and Mississippian faunas. The age of this shale has been the subject of much discussion. Fossils recently collected from the lower and upper parts of the formation in central Kentucky show that both upper Devonian and lower Mississippian strata are present (51, pp. 17, 50). However, the shale in other areas may be either entirely Devonian or entirely Mississippian, and so every area must be considered separately. Although the remarkably uniform character of the shale indicates that conditions of sedimentation must have been similar during late Devonian and early Mississippian time, unconformities reported at some places may indicate at least local breaks in sedimentation whereas at other places, where unconformities have not been recognized, sedimentation may have been continuous.

Whatever its age, this black shale directly underlies undoubted Mississippian strata throughout the Eastern Interior basin except along the border of the Ozark region in western Monroe and southern Calhoun counties, Illinois, and adjacent parts of Missouri, where its absence may be either the result of non-deposition or of pre-Osage erosion. Wherever it crops out around the borders of the basin it lies unconformably on lower beds. The unconformity is particularly marked high on the Cincinnati arch and on the northeast flank of the Ozarks where the shale rests on formations ranging in age from Middle Devonian to Middle Ordovician. The presence of such a pro-

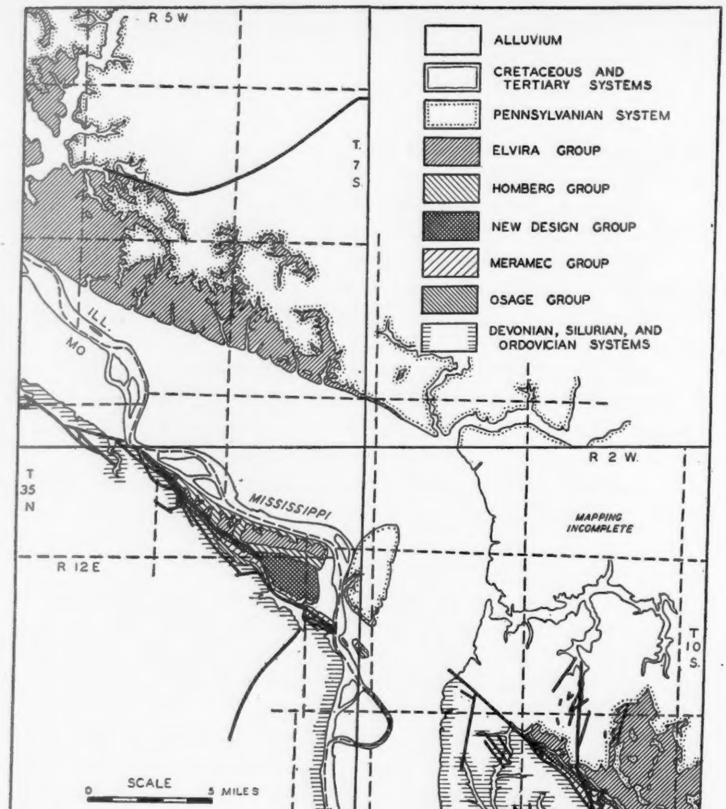


Fig. 5A.—Areal geologic map of parts or all of following quadrangles: Campbell Hill, Murphysboro, Altenburg, Alto Pass, Jonesboro. See index map (Fig. 3). Geologic mapping under auspices of Illinois State Geological Survey and Missouri Geological Survey.

nounced unconformity beneath the black shale in the Mississippi valley has been cited as evidence that the shale is early Mississippian in age, in spite of the fact that its lower portion in Kentucky and Indiana, where an equally great unconformity occurs, is certainly Devonian.

Branson and Mehl have recently pointed out that the conodonts of the lower Kinderhook belong to Devonian genera and mainly on this basis they propose to exclude from the Mississippian system all strata below the base of the Hannibal shale (3, pp. 179–83; 4, p. 5). This conclusion does not appear to be entirely justified, as other faunal evidence is not in harmony.

IOWA SERIES

The Iowa series consists of those beds which for many years have been termed lower Mississippian in distinction from the Chester or upper Mississippian series. It includes the Kinderhook, Osage, and

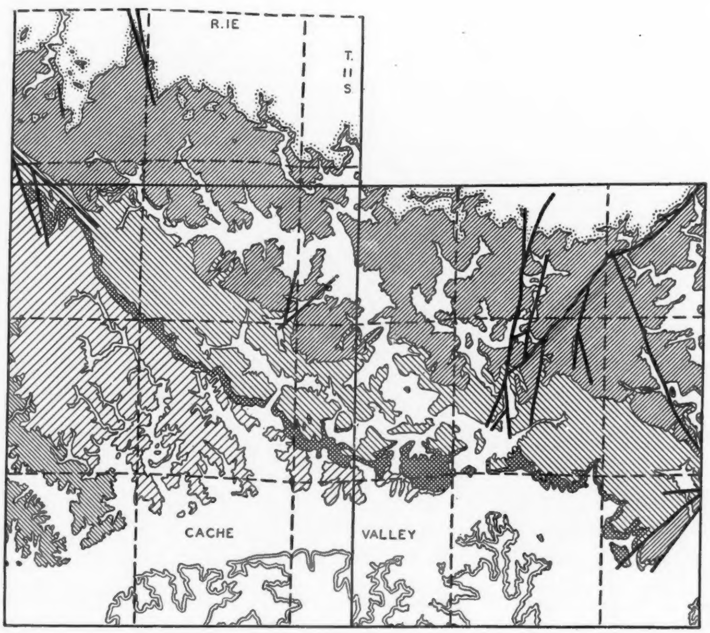


FIG. 5B.—Areal geologic map of parts or all of following quadrangles: Carbondale, Dongola, Vienna. See index map (Fig. 3). Geologic mapping under auspices of Illinois State Geological Survey.

Meramec groups and was named from the state of Iowa in which two of its most important formations, the Burlington and Keokuk limestones, have their typical development. In the Mississippi Valley area the Iowa series is composed principally of massive cherty limestone but eastward it grades irregularly into clastic sediments and in Indiana only the upper part continues as persistent limestone.

KINDERHOOK GROUP

The basal group of the Mississippian system receives its name from Kinderhook, Pike County, Illinois, where good exposures occur in the east bluffs of the Mississippi River valley. Its lithology, stratigraphy, and faunas are so diverse that no single stratigraphic section can be considered typical. It consists of several formations, most of them more or less local in distribution, the correlation of some of which is still tentative.

New Albany shale.—The New Albany shale, of which at least the upper portion at some places is of Kinderhook age, receives its name from New Albany, Floyd County, Indiana. It consists largely of hard, black, sheety shale and is therefore an easily recognized horizon in subsurface work. It crops out in a continuous band extending southeastward through central Indiana from Jasper County to Ohio River and thence encircles the Blue Grass region of Kentucky. At its outcrops in Indiana it varies little in thickness, averaging about 100 feet, but in Kentucky it thins southward so that near the Tennessee state line it averages only 25–35 feet thick. It thickens, however, toward the deepest part of the basin, as drillings in Kentucky record 150 feet near Bowling Green, 160 feet near Owensboro, 242 feet near Princeton, and 255 feet near Kuttawa, and on Hicks dome in Hardin County, Illinois, where it has been called Chattanooga shale, it has a reported thickness of 400 feet (87, p. 87)

Mountain Glen shale.—A hard, black, sheety shale, which crops out in southwestern Illinois and which has been named Mountain Glen shale after a town in Union County, is correlated with the upper part of the New Albany shale (50, p. 177). It lies unconformably on Devonian limestone and attains a maximum thickness of nearly 50 feet.

Grassy-Saverton shale.—The name Grassy Creek was originally proposed by Keyes (28, p. 63) for "black and green shales" lying beneath the Louisiana limestone at Louisiana and elsewhere in Pike County, Missouri. Later, Keyes restricted this name in abbreviated form to the lower, black beds and proposed the name Saverton for the upper greenish or bluish beds (29, p. 160). Subsequently Krey

(30, p. 23) determined that, although black shale of Mississippian age does occur in the drainage basin of Grassy Creek, the dark shales conspicuously exposed along that stream (correlated by Keyes and Rowley (28, p. 63; 45, p. 24) with the black shale at Louisiana) are not equivalent to the beds exposed at Louisiana, as they respectively underlie and overlie the Silurian Noix oölite which is locally absent along Grassy Creek. Re-study of these localities has demonstrated that the black shale on Grassy Creek is a member of the Maquoketa and if this place be accepted as the type locality the name Grassy Creek or Grassy may not be used for the black shale at the base of the local Mississippian section. It has been proposed by Weller (73), therefore, that the name Saverton be expanded to include the black shale lying conformably beneath the typical Saverton.

Because the basal black shale of the Kinderhook and that of the overlying greenish or bluish beds appear to be perfectly conformable, and because the black shale is believed to grade laterally into lighter-colored and less laminated shale, it is doubtful if these two members deserve recognition as separate formations. Branson and Mehl (3, pp. 171–74), as well as others, have continued to refer to this entire interval as Grassy Creek shale. Because of uncertainty regarding the status of the names Grassy Creek and Grassy, the term Grassy-Saverton shale is tentatively employed in this paper.

The Grassy-Saverton shale consists in ascending order of thin basal sandstone, black, hard, sheety shale, and thicker, bluish or greenish argillaceous shale. The basal sandstone, a few inches thick, is present at Louisiana and other places in Pike County, Missouri. It is generally well cemented, weathers to a brownish color, and is distinguished by abundant fish teeth, bone fragments, coprolites, and black phosphatic nodules.

The black shale member is thinly laminated, hard, brittle, and very carbonaceous. It is 20 feet thick in parts of Pike and Calhoun counties, Illinois, but at Louisiana, Missouri, it is only 4 feet thick, and farther south it thins and disappears. It is reported in wells for some distance east, north, and possibly west, beyond its area of outcrop. Farther northeast, however, it loses its black color and becomes dark gray silty shale.

The main and uppermost or Saverton member of the formation consists of bluish or greenish argillaceous shale which is 80 feet thick at its type locality near Saverton although it is said to increase to 100 feet elsewhere in Ralls County. This shale thins southward, being only 1½–2 feet thick at Louisiana, but extends beyond the limit of the underlying black shale member before it pinches out entirely. It is

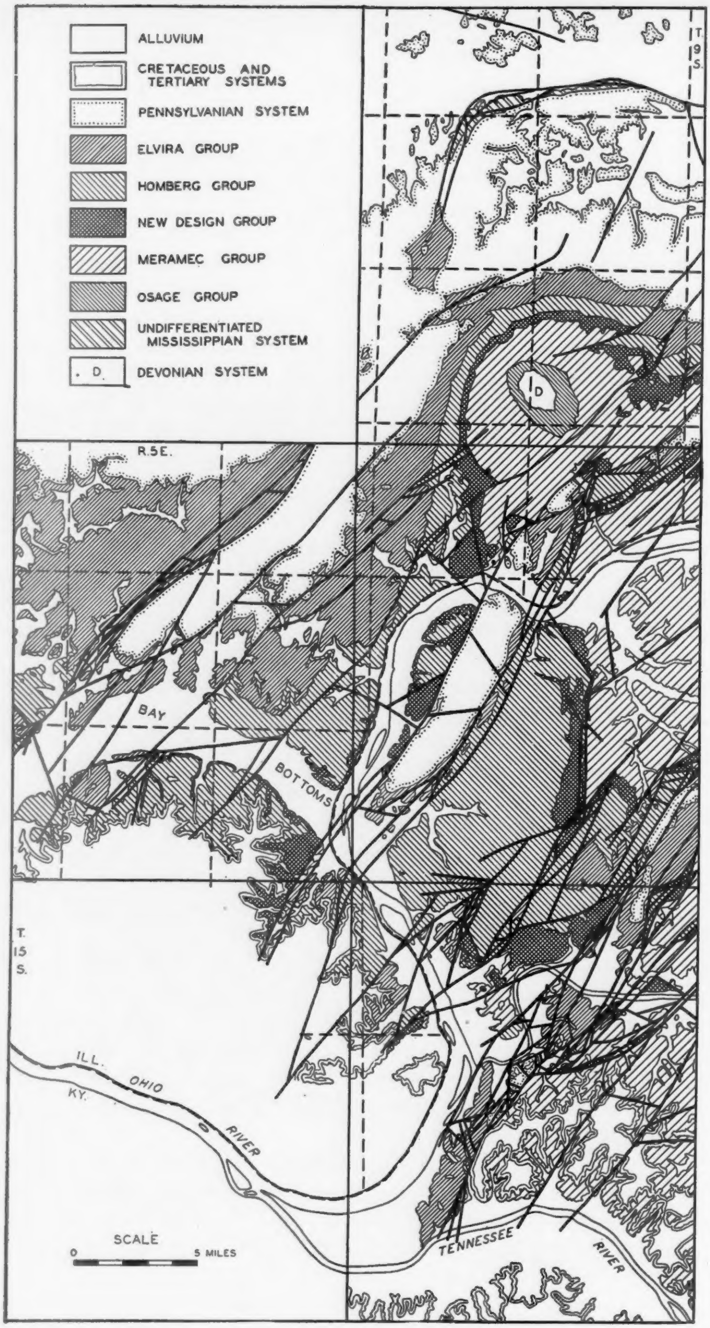


FIG. 6A.—Areal geologic map of parts or all of following quadrangles: Equality, Brownsfield, Golconda, Paducah, Smithland. See index map (Fig. 3). Geologic mapping under auspices of Illinois State Geological Survey and Kentucky Geological Survey.

FIG. 6B.—Areal geologic map of parts or all of following quadrangles: Shawneetown, Cave in Rock, Providence, Eddyville, Princeton, See index map (Fig. 3). Geologic mapping under auspices of Kentucky Geological Survey and Illinois State Geological Survey.

below drainage on the north at Hannibal but crops out in central Marion County, Missouri, and its presence in a considerable area beyond is revealed by drill records.

The Grassy-Saverton shale is apparently equivalent to part of the lower Kinderhook section of southeastern Iowa, where it has been designated "Kinderhook Bed 1" at Burlington (76, p. 60) and Maple Mill shale in Washington County (1, p. 127), and probably also to the Sweetland Creek beds of Muscatine County.

The Grassy-Saverton shale lies unconformably on beds ranging in age from Ordovician to Devonian and appears to pass conformably into the Louisiana limestone above. It is possible that the great thickness of this limestone at Louisiana, where the Saverton is thin, and the much thinner Louisiana limestone farther north, where the Saverton is thicker, is evidence that the Louisiana limestone began to be deposited on the south while Saverton shale was still accumulating on the north.

Sweetland Creek beds.—A series of about 50 feet of interbedded black and greenish shale and argillaceous magnesian limestone which is exposed along the Mississippi valley in southern Muscatine County, Iowa, has been named Sweetland Creek after the stream along which the beds are best exposed (62, p. 289). These beds rest unconformably on the Cedar Valley limestone (Devonian) and are overlain also unconformably by Pennsylvanian sandstone. The basal layer contains

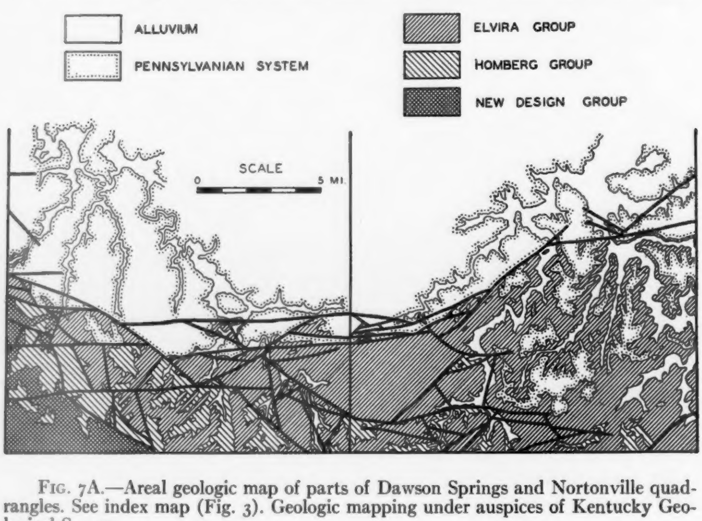


FIG. 7A.—Areal geologic map of parts of Dawson Springs and Nortonville quadrangles. See index map (Fig. 3). Geologic mapping under auspices of Kentucky Geological Survey.

abundant fish teeth, but as no diagnostic fossils are known the age of these beds is somewhat uncertain. They have been considered Devonian by some (62, pp. 301–03; 13, pp. 192–97), but the more recent tendency is to include them in the Kinderhook series (82, p. 274; 67, p. 71; 41, p. 36; 33, p. 352).

In recent reports of the Illinois State Geological Survey the name Sweetland Creek shale has been used for a series of dark-colored shales commonly reaching a thickness of 100–200 feet and encountered in deep wells between the Devonian and Mississippian limestones. The shales contain numerous spores similar to, or indentical with, *Sporangites huronense* which are common in the black shales of the New Albany, Mountain Glen, Grassy-Saverton, and Sweetland Creek formations and also occur in certain parts of the lighter-colored shales of the Saverton and Sweetland Creek formations, in another black shale overlying the Glen Park limestone of Missouri, and in the Hannibal shale. It follows therefore that the "Sweetland Creek" shale of Illinois subsurface studies may include representatives of any or all of the afore-named formations.

Almost every well that has penetrated to sufficient depth in the entire Eastern Interior basin has encountered dark *Sporangites*-bearing shale between the Devonian and Mississippian limestones and it is clear that the New Albany shale of Indiana and central Kentucky, the "Chattanooga" shale of southeastern Illinois, the Mountain Glen shale of southwestern Illinois, the Grassy-Saverton shale of northeastern Missouri, and the Sweetland Creek shale of

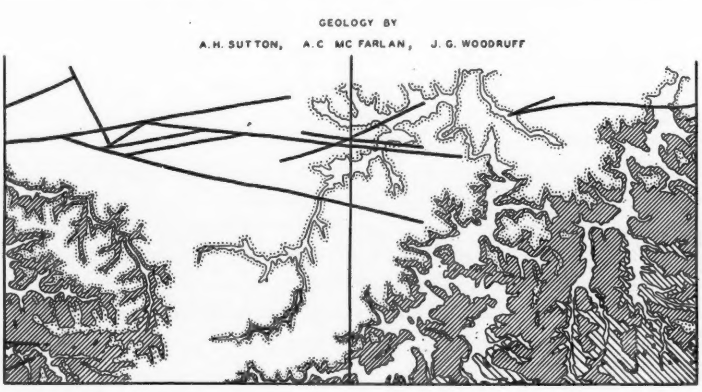


FIG. 7B.—Areal geologic map of parts of Drakesboro and Dunmor quadrangles. See index map (Fig. 3). Geologic mapping under auspices of Kentucky Geological Survey.

southeastern Iowa are the outcropping edges of a continuous, extensive, and easily recognized series of dark shales all more or less equivalent although not necessarily of exactly the same age.

Louisiana limestone.—A conspicuous lithographic limestone member of the Kinderhook series in northeastern Missouri is named Louisiana after the town of Louisiana in Pike County. This limestone is dense, fine-grained, and light gray where fresh but weathers to light yellowish brown. It occurs in evenly bedded layers with distinct partings and breaks with a conchoidal fracture. The Louisiana crops out at many places in Marion, Ralls, and Pike counties, Missouri, reaching a maximum thickness of nearly 70 feet near Ilasco in Ralls County. It rarely exceeds a thickness of 5 feet in Illinois and pinches out completely in southern Calhoun County. To the north it thins as the Saverton shale thickens, suggesting that the upper part of the Saverton shale in the north may have accumulated contemporaneously with the lower part of the Louisiana where it is best developed.

The McCraney[7] lithographic limestone in Pike County, Illinois, (41, pp. 20–23, 49–60) and the lithographic bed at Burlington, Iowa, are lithologically similar to the Louisiana limestone and future studies may prove them to be equivalent.

Sulphur Springs formation.—The Sulphur Springs formation in southeastern Missouri consists of an unnamed basal shale member, the Glen Park oölitic limestone in the middle, and the Bushberg sandstone at the top, all three names being derived from towns in Jefferson County. The basal shale is argillaceous and yellowish brown. It is known to crop out only in its type area, where it attains a thickness of 15 feet. This may represent the Saverton shale of northeastern Missouri. The Glen Park limestone, which ranges in thickness from 1 to 15 feet, is light gray, more or less impure oölitic limestone at its type locality but farther south in Ste. Genevieve County it is gray to yellowish arenaceous limestone with lenticular oölitic beds and contains phosphatic nodules. The Bushberg sandstone, which has a maximum thickness of about 10 feet, is soft, coarse, and yellowish brown. Locally its basal portion is a conglomerate containing phosphatic pebbles and fish teeth. It is probably equivalent to the lower part of the Hannibal shale.

The Sulphur Springs formation lies unconformably on Ordovician strata. In Ste. Genevieve County it is overlain by hard, black, evenly laminated *Sporangites*-bearing shale which is also probably equivalent to part of the lower Hannibal shale.

[7] This member takes its name from a creek that reaches the Mississippi bottoms a short distance above Kinderhook. In the original paper (41) the name was incorrectly spelled McKerney.

Hannibal formation.—The name Hannibal, after a town in Marion County, Missouri, has been given to a series of siliceous shales with more or less sandstone, which reaches a maximum thickness of about 100 feet in Pike County, Missouri, and northern Calhoun County, Illinois, and thins south and southwest. The formation is characteristically bluish or brownish green and weathers to a brownish color. In its southern exposures it is mainly a non-laminated earthy shale but northward it becomes increasingly siliceous and coarser-grained and consists more or less of very fine sandstone or siltstone in which worm borings are locally abundant. Because of these borings it has been termed the Vermicular sandstone.

At the base of the Hannibal formation in Jersey and Calhoun counties, Illinois, and St. Charles County, Missouri, occurs a maximum thickness of 25 feet of sandy limestone, some beds of which are more or less oölitic, interstratified with shales. These beds have been named the Hamburg oölite after the town of Hamburg, Calhoun County, Illinois, where they immediately overlie the Louisiana limestone. The fauna of the Hamburg oölite is similar to that of the Glen Park limestone in the Sulphur Springs formation of southeastern Missouri. In Calhoun County, Illinois, dark laminated shale occurs in the middle part of the Hannibal formation.

The Hannibal formation as recognized near Kinderhook, Illinois, and at Burlington, Iowa, is divisible into four members (30, pp. 36–37; 41, pp. 20–24). The Maple Mill shale at the base consists of bluish argillaceous beds that are locally calcareous or silty. This member grades upward into the English River (or *Conopectus*) sandstone, which is massive, fine-grained, and weathers to a buff color. They are each about 20 feet thick at Burlington but achieve about double that thickness at Kinderhook. These are succeeded by the McCraney (McKerney) member consisting of gray to drab lithographic limestone up to 15 feet thick which at Burlington is underlain by a few inches of gray crystalline limestone and white oölite and is overlain by a foot or two of brownish dolomitic limestone. At the top is the Prospect Hill member, a soft drab-weathering fine-grained sandstone 6 feet thick at Burlington and 10 feet thick at Fall Creek, Illinois.

The McCraney limestone is lithologically similar to the Louisiana limestone and as these two beds have nowhere been observed in the same section it is possible that they are equivalent. If so the Maple Mill shale and English River sandstone are members of the Saverton. Both of these names, however, are derived from localities in Iowa considerably removed from the various well known Kinderhook sections and their relations to each other and to these sections have not yet been fully established.

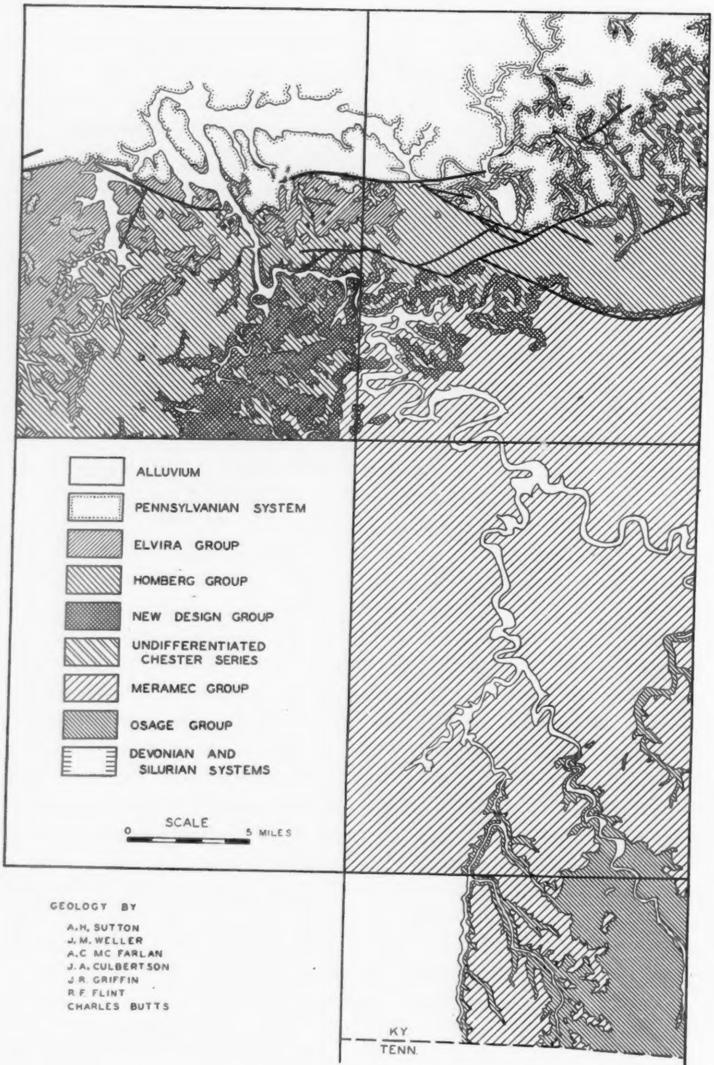


FIG. 8A.—Areal geologic map of part or all of following quadrangles: Little Muddy, Brownsville, Bowling Green, Adolphus. See index map (Fig. 3). Geologic mapping under auspices of Kentucky Geological Survey.

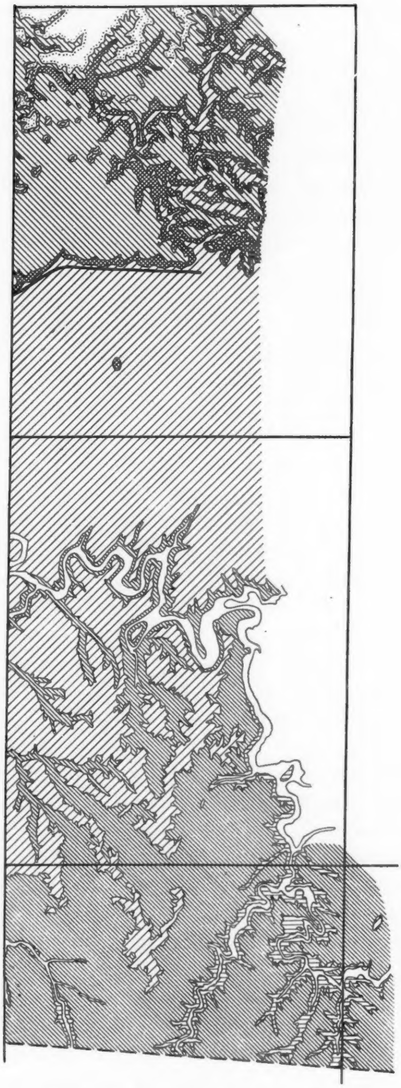


FIG. 8B.—Areal geologic map of part or all of following quadrangles: Mammoth Cave, Scottsville, LaFayette, Red Boiling Springs. See index map (Fig. 3). Geologic mapping under auspices of Kentucky Geological Survey.

Springville shale.—A shale, with a maximum thickness of about 60 feet, which crops out in southwestern Illinois, has been named Springville from a village in Union County. It is bluish to greenish gray where fresh but weathers to a variegated mottling of white, red, and brown for which reason it was termed "Calico shale" in the Worthen reports. The lower part of this formation is soft and argillaceous with occasional calcareous layers, but the upper part is hard and silicified. It overlies the black Mountain Glen shale unconformably and rests on Devonian limestone where the black shale is absent. It also is reported to be unconformable with the overlying cherty limestones of Osage or Meramec age. Fossils are rare in the Springville shale but are present in a thin limestone locally present at the base of the formation and prove its Kinderhook age. It is tentatively correlated with the Hannibal formation.

Chouteau limestone.—The uppermost formation of the Kinderhook series in the western part of the Eastern Interior basin is correlated with the Chouteau limestone of central Missouri. It is dolomitic, earthy, lithographic, or crystalline in texture, is brownish, gray, or almost white in color, and contains many small calcite geodes. It reaches its maximum thickness of about 60 feet in Calhoun County, Illinois, but is absent throughout a considerable area where over- and underlying beds are in contact. It succeeds the Hannibal formation conformably and thins where the Hannibal thickens so that their combined thickness remains nearly constant.

At Burlington, Iowa, the Chouteau is probably represented by a 3-foot oölitic limestone which occurs at the top of the Kinderhook section.

Rockford limestone.—A thin limestone of very constant lithologic character is the only representative of the Kinderhook series definitely recognized in Indiana. It is named from Rockford in Jackson County where it has yielded an interesting fauna, including numerous goniatites on account of which it was formerly known as the Goniatite limestone. The Rockford limestone commonly varies in thickness from 1 to a maximum of 3 feet and, except at its thicker exposures, consists of a single bed which produces many small waterfalls. It is dense brittle limestone of almost lithographic texture, gray mottled with greenish specks and streaks where fresh, but weathers to yellowish brown. Beneath it and separating it from the New Albany shale at many places is a 2- to 6- inch zone of bluish green clay shale with green glauconitic specks. The Rockford limestone is uniformly present from its type locality southward to Ohio River but has not been recognized in Kentucky. Although its fauna is suggestive of the

Chouteau it can not be definitely correlated with any of the Mississippi Valley formations.

KINDERHOOK SEDIMENTATION

The conditions of deposition of the remarkably uniform black shale, which may in part constitute the base of the Kinderhook group throughout nearly all of the Eastern Interior basin, have been the subject of much difference of opinion but it seems most likely that these beds are an accumulation of colloidal material carried from low-lying land into an extensive shallow sea. Coarser clastic materials form a conspicuous part of the succeeding strata in the Mississippi valley and on the flank of the Ozark region, and possibly also northwestward in Iowa they overlap the black shale onto older beds. The absence of easily recognizable Kinderhook beds, except the thin Rockford limestone, along the eastern border of the basin suggests either that the New Albany shale may include in its upper part beds representing nearly the entire Kinderhook series or that this area was largely emergent during Kinderhook time.

Sedimentary conditions in the Kinderhook sea varied greatly from place to place and from time to time but the causes for this variation are not known. Ozarkia existed as a land area for a time at least, because the Bushberg sandstone of southeastern Missouri and the Sylamore sandstone of central Missouri, with which it has been correlated, contain grains that were almost certainly derived from Ordovician beds cropping out on the southwest and south. Clastic sediments were probably derived to a greater extent, however, from other sources. The Hannibal formation thickens and becomes more sandy toward the north and these sediments may have been derived from the erosion of earlier Paleozoic formations exposed in northern Illinois and adjacent area. The clastic character of the Waverly series of Ohio, the lower portion of which is certainly Kinderhook in age, is evidence that Appalachia was a land area undergoing erosion during early Mississippian time, but the absence of similar strata along the eastern margin of the Eastern Interior basin suggests that the Cincinnati arch at this time may have existed as an effective barrier separating two sedimentary provinces.

KINDERHOOK PALEONTOLOGY

The Kinderhook group is generally non-fossiliferous, but restricted horizons at some localities contain an abundance of specimens. These faunas of restricted distribution evidently reflect local ecological factors and consequently are so varied that precise correlation of the strata is difficult. They fall into two general types, how-

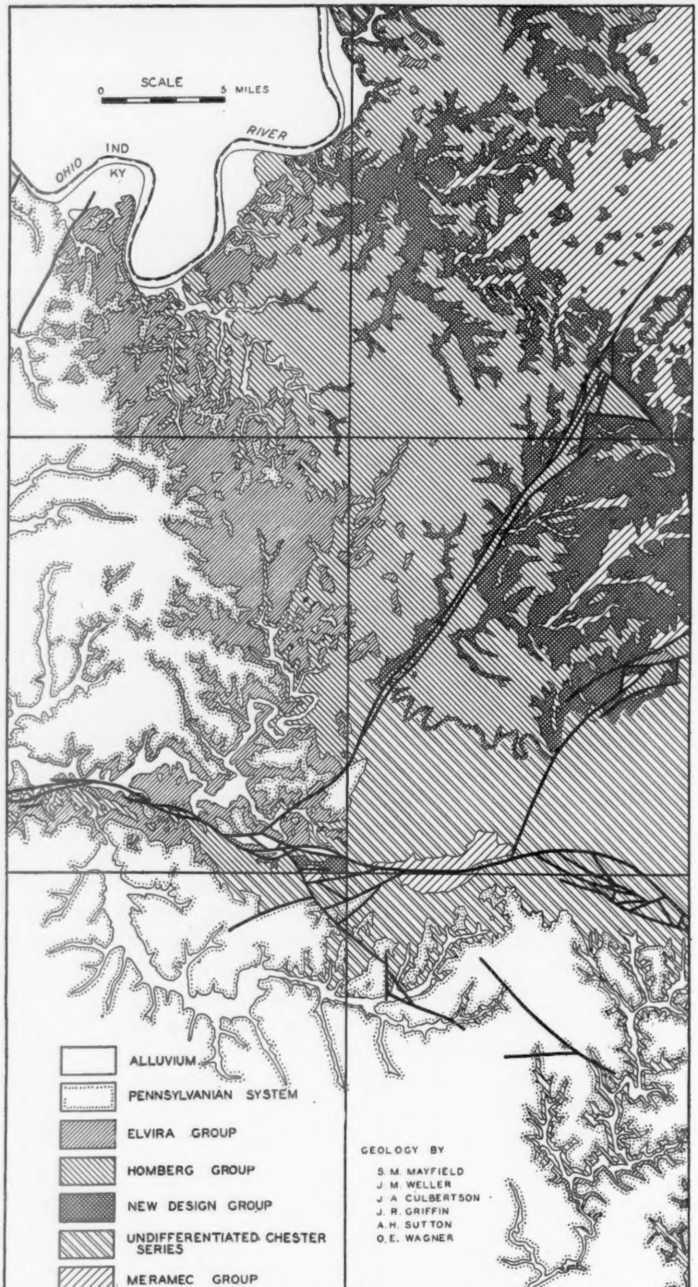


FIG. 9A.—Areal geologic map of part or all of following quadrangles: Cannelton, Hardinsburg, Falls of Rough, Kirk, Spring Lick, Leitchfield. See index map (Fig. 3). Geologic mapping under auspices of Kentucky Geological Survey.

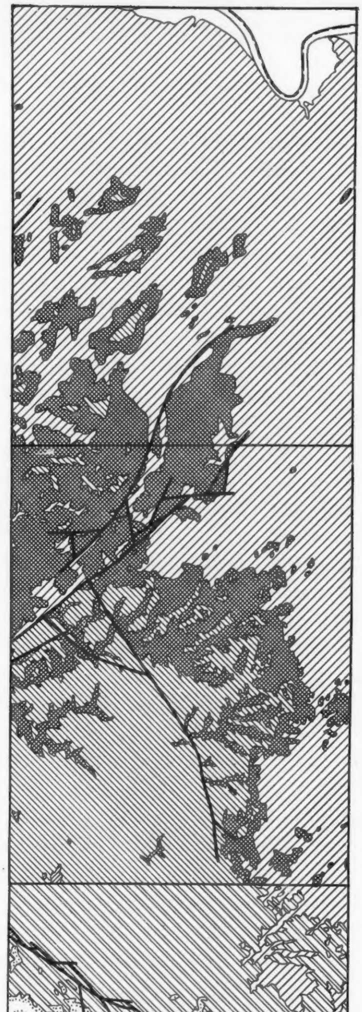


FIG. 9B.—Areal geologic map of part or all of following quadrangles: one unnamed, Big Clifty, Cub Run. See index map (Fig. 3). Geologic mapping under auspices of Kentucky Geological Survey.

ever, one of which is represented in the English River (*Chonopectus*) sandstone and the Louisiana limestone and the other is characteristically developed in the Chouteau limestone and occurs also in the Glen Park limestone and Hannibal formation. The differences between these faunas are not obvious, but the *Chonopectus* fauna contains residual Devonian elements most closely related to the Chemung of New York while similar forms in the Chouteau fauna have Hamilton relationships. Although the *Chonopectus* fauna occurs in beds which underlie those containing the Chouteau fauna, it is not necessarily older, as regional considerations suggest that at first the *Chonopectus* and Chouteau faunas existed contemporaneously in different basins or different parts of the same basin and that after a change of conditions in mid-Kinderhook time the Chouteau fauna migrated and supplanted the *Chonopectus* fauna in the upper Mississippi Valley area.

Because the Kinderhook faunas vary so greatly, index fossils are of only local value. However, certain genera, including the brachiopods *Paraphorhynchus* and *Chonopectus* and the pelecypod *Promacrus*, which are represented by one or more species in the Kinderhook series, are unknown from other formations in the Eastern Interior basin. The Mississippian age of the Kinderhook series is attested by several species of *Productidæ* which are associated with the last representatives of *Productella*. Spirifers of Devonian and Mississippian types are intermingled. *Spirifer louisianensis* is one of the most common species of this genus and occurs in both the *Chonopectus* and Chouteau faunas, and spirifers of high form with very narrow hinge lines, such as *S. subrotundatus* and *S. maplemillensis*, are characteristic of certain horizons. The molluscs, particularly pelecypods, are unusually well represented and provide the faunas with a strong Devonian aspect.

KINDERHOOK-OSAGE RELATIONS

The broader stratigraphic relations between the Kinderhook and Osage groups are somewhat uncertain but along the western border of the Eastern Interior basin they are generally unconformable. Definite physical evidence of an unconformity has been observed in Calhoun and in Pike counties, Illinois. In Marion, Ralls, and Pike counties, Missouri, and the adjacent part of Illinois, the Chouteau limestone is locally absent and appears to have been removed by erosion before the lowest Osage beds were deposited. In western Monroe County, Illinois, the Kinderhook is entirely absent and the Fern Glen formation (lowest Osage) rests on Ordovician strata,

although black shale similar to the New Albany is recorded in wells only a short distance east and the Sulphur Springs formation is present locally in Ste. Genevieve County, Missouri, on the west. In Union County, Illinois, the Springville shale is reported to be succeeded unconformably by middle Mississippian limestone.

It seems probable, however, that along the eastern border of the basin, no appreciable erosion occurred between the Kinderhook and the Osage epochs of sedimentation, because in southwestern Indiana, western Kentucky, and Hardin County, Illinois, no unconformity has been recognized. In Jefferson County, Kentucky, transitional beds have been reported to connect the New Albany with the overlying New Providence shale.

OSAGE GROUP

The Osage group, which receives its name from Osage River in Missouri, consists of a conformable series of more or less cherty limestones with subordinate amounts of shale. The constituent formations in the type areas have been separated mainly on the basis of lithology, and their faunas, which form a single slow evolutionary series not dependent on profound physical changes or extensive immigration of new forms, have been determined accordingly. The lithology of the various formations, however, changes laterally to such an extent that the formation boundaries can not be extended uniformly far from the type localities, and in areas of thick glacial drift and discontinuous exposures it may be impossible to subdivide the Osage group satisfactorily. The name Augusta limestone has been used in southeastern Iowa and northeastern Missouri for undifferentiated beds approximately equivalent to the Osage group. In Indiana beds of Osage age constitute the Borden group.

Fern Glen formation.—The Fern Glen formation, which is named from Fern Glen station on the Missouri Pacific Railroad 20 miles west of St. Louis, is also typically developed near Kimmswick, Missouri, and Valmeyer, Illinois. It consists of 25 to 35 feet of red calcareous shale and somewhat cherty limestone which grades upward through greenish beds into light-colored cherty Burlington limestone. The lower boundary of the Fern Glen formation is generally sharply defined, and locally it succeeds older beds with marked unconformity, as follows: the Maquoketa shale (Ordovician), near Valmeyer, Illinois; the Fernvale limestone (Ordovician) at Brickeys in Ste. Genevieve County, Missouri; the St. Laurent limestone (Devonian) at several places in Perry County, Missouri; the Bushberg sandstone (Mississippian) near Kimmswick, Missouri; the black

shale above the Bushberg at one locality in Ste. Genevieve County, Missouri; and the Chouteau limestone at Chautauqua in Jersey County, Illinois.

The Fern Glen formation is easily recognized by its red color as recorded in the logs of wells drilled some distance east of its outcrop area and south as far as Chester. Toward the north the red color disappears and the formation becomes less shaly and is not recognized by these characters beyond Jersey County, Illinois.

Sedalia limestone.—The name Sedalia has been proposed (41, p. 149) for limestone beds in central Missouri which contain a Fern Glen fauna and which have been designated by previous authors as upper Chouteau.[8] In the Mississippi Valley region above Jersey County, Illinois, the beds of Fern Glen age do not possess the typical lithologic characters of that formation but resemble the typical Sedalia limestone and are accordingly referred to it.

The Sedalia limestone of the Mississippi Valley region is generally brownish gray, earthy, dolomitic, and commonly somewhat less resistant to weathering than the underlying Chouteau or overlying Burlington beds. It is uniformly present as far north as Kinderhook with a thickness of 10–40 feet but has not been recognized at Hannibal and is apparently absent to the north as far as the base of the Osage group is exposed. It is present in southeastern Iowa, however, where it consists of magnesian limestone which has a thickness of 3–5 feet at Burlington. Farther northwest the Wassonville limestone is apparently equivalent to the Sedalia. Like the Fern Glen, the Sedalia lies unconformably on the Chouteau limestone and older beds.

Burlington limestone.—The Burlington limestone is about 70 feet thick at its type locality near Burlington, Iowa, 100 feet thick in parts of northeastern Missouri, nearly 200 feet thick in Calhoun County, Illinois, and then thins to about 75 feet in Ste. Genevieve County, Missouri. In southeastern Iowa and adjacent portions of Illinois and Missouri, the Burlington formation consists of very pure, coarsely crystalline, and generally light-colored limestone with subordinate amounts of denser brownish dolomitic rock and beds or irregular masses of chert. At many places the purer limestone layers are composed almost entirely of fossil remains, especially fragments of stems, arms, and bodies of crinoids. The top of the Burlington limestone is marked throughout a wide area by a bed 2 to 10 inches thick which contains an unusual abundance of fish teeth and spines.

To the south the Burlington limestone becomes more cherty and in Ste. Genevieve County, Missouri, and Monroe County, Illinois,

[8] Branson does not recognize this subdivision of the original Chouteau and considers the Fern Glen to be a lateral facies variation of the Chouteau (4, pp. 12, 16–17).

bedded and irregular chert may constitute as much as 50 per cent of the formation, crystalline limestone beds are fewer, dense gray strata are more common, and fossils are much less abundant. In this region no distinct lithologic change occurs between the Burlington and Keokuk formations and they can be distinguished only by their fossils.

The Burlington limestone lies conformably on the Fern Glen and Sedalia formations and unconformably on older beds where the Fern Glen and Sedalia are absent.

Keokuk limestone.—The Keokuk formation, which is typically developed near Keokuk in southeastern Iowa and in adjacent parts of Illinois and Missouri, consists of 60–80 feet of interbedded limestone and chert with minor amounts of shaly material. The lower 30 feet is very cherty limestone known as the Montrose member. The limestone beds of the Keokuk vary from dense to crystalline but are generally darker and more bluish than similar strata in the Burlington.

On the south the Keokuk remains almost constant in thickness but becomes much more cherty. In Ste. Genevieve County, Missouri, it is separated into two parts by an apparent unconformity, below which the beds are lithologically indistinguishable from the Burlington and above which occurs siliceous or arenaceous limestone which passes laterally into oölite succeeded by grayish crystalline limestone with much chert. Some of the chert from the upper Keokuk weathers porous and spongy, greatly resembling ferruginous sandstone, and is very different from the dense, hard, brittle chert from lower horizons.

Burlington-Keokuk formation of southern Illinois and western Kentucky.—The increasing chert in the Burlington and Keokuk limestones on the south has been mentioned. The limestones can not be distinguished lithologically in the 100–150 feet of cherty limestone in Monroe County, Illinois, and Ste. Genevieve County, Missouri, although the fossils show that both formations are present. Farther south in Union County, Illinois, and east in Hardin County, Illinois, the Osage group consists largely of more or less evenly bedded limestone that is fine-textured, dark in color, and very siliceous. Much chert is present, and generally in Union County the lower part to a maximum thickness of about 30 feet consists of solid-bedded novaculite chert. Fossils are rare and most of them are too poorly preserved to be accurately identified, so that it is impossible to determine whether the Fern Glen, Burlington, and Keokuk are all represented in these sections. The thicknesses, however, estimated as 250–300 feet in Union County and 500–600 feet in Hardin County, suggest that the group is probably complete.

The cherty Osage beds of southern Illinois have been referred to

the Fort Payne (Tullahoma) formation of Tennessee and Alabama but as the boundaries of this formation are somewhat vague and its various parts of uncertain age, it seems preferable to designate them simply Burlington-Keokuk.

New Providence formation.—The name New Providence, which has been given to the basal formation of the Borden group, as the Osage group is termed in Indiana, is derived from the old name of the town of Borden in Clark County, Indiana. It decreases in thickness from 290 feet in Jackson and western Bartholomew counties, Indiana, to 190 feet in Jefferson and 50 feet in Pulaski counties, Kentucky. This formation is composed mainly of argillaceous poorly bedded bluish to greenish-gray shale, which readily weathers to lighter-colored clay. "Ironstone" is distributed throughout the whole formation but is more abundant in the lower part. It occurs either as continuous layers or nodules of various forms, which weather to impure limonite. Less ferruginous limestone masses or concretions which may or may not be fossiliferous and some of which are cherty are conspicuous at some localities, particularly in the vicinity of Ohio River. In Jefferson County, Kentucky, the upper 30 to 40 feet of the New Providence formation contains interbedded sandstone layers and has been termed the Kenwood sandstone from Kenwood Knob, 9 miles south of New Albany. This zone decreases in thickness both northward and southward and has not been recognized beyond east-central Floyd County, Indiana, and Lebanon Junction in Bullitt County, Kentucky. In central Brown County, Indiana, beds that appear to belong to the New Providence formation consist of heavy sandstones with thin sandy shale partings.

Southwest of the Blue Grass region of Kentucky the New Providence formation thins considerably and in Allen County, just north of the Tennessee state line, it is believed to be represented by 40 feet of grayish green shale and shaly limestone with a few rather massive layers of crinoidal cross-bedded limestone. A little chert is present and geodes are locally common.

Locust Point formation.—The Locust Point formation, which conformably overlies the New Providence, is named from Locust Point Post Office in Harrison County, Indiana. Its nearly uniform thickness is about 125 feet. From Jackson County, Indiana, southward to Ohio River it consists of slightly sandy argillaceous shale, greenish gray to bluish gray, closely resembling the New Providence shale and grades upward into shaly sandstone interbedded with grayish drab shale that weathers buff. Highly ferruginous concretions are present but are less abundant than in the underlying New Providence formation and

those in the upper part are commonly sandy. Brittle fine-grained nonferruginous limestone concretions are also present in the Locust Point formation and are more abundant in its upper part.

In northwestern Jackson County, Indiana, numerous sandstone layers abruptly appear in the Locust Point formation. They are more or less massive, evenly laminated, and weather into thin layers. Some of their surfaces show ripple marks. These sandstones are greenish gray to buff, locally chocolate-colored, and contain abundant ferruginous streaks and patches. The interbedded shales are very sandy and contain few concretions. The sandstones become thicker northward in Brown County. Eastward in Bartholomew County, where these beds have been quarried, they are relatively resistant and one sandstone 70 feet above the New Providence appears to be unusually persistent. In Monroe and western Brown County the interbedded shales become much less sandy, contain ferruginous concretions, and closely resemble the New Providence shale.

The Locust Point formation is nearly destitute of fossils except worm markings, which are abundant at many places, particularly in the upper part. It is approximately equivalent to the Rosewood shale of Jefferson County, Kentucky, which was named from the town of Rosewood in Harrison County, Indiana. Neither the Locust Point nor Rosewood formation has been distinguished in the Osage section south of Jefferson County, Kentucky

Carwood formation.—The Carwood formation, named from the village of Carwood in Clark County, Indiana, is the most variable of the Borden formations. It overlies the Locust Point formation conformably and can not be sharply differentiated from it. Its thickness is almost uniformly about 120 feet. In the area of its typical development, which extends from northeastern Floyd to northeastern Washington County, the Carwood formation consists of light gray to bluish gray, locally iron-stained, massive but soft, arenaceous siltstone or fine sandstone that lacks conspicuous bedding and weathers drab to buff or brown. At the top of the formation occurs the Finley Knob member composed of gray to drab, locally sandy shale with a maximum thickness of 15 feet.

Northward the Carwood formation becomes more shaly, and in northern and northeastern Washington County it consists of irregular alternating shaly and sandy zones. From northwestern Washington to Brown and Monroe counties it is a nearly uniform succession of siltstones and sandy shales. In southwestern Brown and southeastern Monroe counties it is separated into two parts by the Lampkins sandstone member, which is a fine-grained gray to buff resistant

bed 1–4 feet thick occurring slightly below the middle of the formation. In this area the lower Carwood is bluish gray shale which weathers readily to clay, contains a few thin beds of sandstone, and resembles the New Providence shale. The upper part is a succession of very thinly and evenly laminated sandstone beds separated by shales. In northern Monroe, south-central Morgan, and northwestern Brown counties the Carwood is almost entirely shale, which is more sandy in the upper part but practically devoid of sandstone beds. To the east, throughout most of Brown County, this formation is exceedingly variable and more arenaceous. Plastic argillaceous shales are lacking and locally at the top there are beds of light gray sandstone of coarser texture than common.

In Floyd and Harrison counties, Indiana, and Jefferson County, Kentucky, south of its area of typical development, the Carwood formation is less arenaceous and contains a greater proportion of shaly beds in its lower part. Along Ohio River in southern Harrison County, Indiana, the massive sandy lithology of the Carwood disappears and the upper part becomes slightly but increasingly calcareous toward the south.

South of Monroe and Brown counties, Indiana, calcareous zones consisting of dense, brittle limestone layers and crinoidal lenses are present in the Carwood formation. Gray calcareous brown-weathering concretions similar to some of those in the Locust Point formation, many of which are fossiliferous, are locally particularly abundant in the middle and upper parts of the Carwood and a few small geodes are present at some places. Other concretions that are ferruginous and sandy are most common in the lower part.

Fossils, which are almost entirely absent from the Locust Point formation except for worm markings, are locally common in the Carwood formation. In general the faunules in the arenaceous beds of the formation are dominated by large brachiopods, and bryozoans are the most common fossils in the shaly strata. Worm markings are also locally abundant.

The Carwood formation is equivalent to the Holtsclaw sandstone and the upper part of the Rosewood shale of Jefferson County, Kentucky. None of these formations, however, has been differentiated in the Osage section farther south in Kentucky.

Edwardsville formation.—The Edwardsville formation, which forms the top of the Borden group, has been recognized from Warren County, Indiana, to Ohio River and in adjacent parts of Kentucky. It is named from the town of Edwardsville in Floyd County, Indiana, and increases from a minimum thickness of 45 feet near Ohio River northward to a maximum of 210 feet.

At the base of the Edwardsville is the persistent Floyds Knob member[9] which in its type area extending from northeastern Lawrence County to Ohio River, except for parts of western Clark County, consists of limestone varying in thickness, generally 3–5 feet. This member varies from almost pure limestone to very siliceous, dolomitic, ferruginous limestone that weathers to a deep yellow or chocolate color. At some places the entire rock is intermediate between these extremes and at others they are represented in different beds or different parts of the same bed. The purer limestone is crinoidal, crystalline, or oölitic and ranges from light to dark gray in color. The impure limestone leaches to a soft, porous, poorly cemented, sandy bed which crumbles to ocherous sand or silt. In parts of western Clark and adjoining counties the Floyds Knob member is represented by a single hard brittle sandstone bed or several thin sandstone layers. This member is apparently absent from the section in part of northwestern Washington County.

From northeastern Lawrence to Warren County, the Floyds Knob member consists of irregular silty calcareous brittle shaly or arenaceous strata which commonly include small nodules of chert. It weathers to a light buff, yellowish, or chocolate color or may be mottled. Where the Floyds Knob member is succeeded by calcareous beds it may not be distinguishable from them or may be represented by a thin bed of limestone that is commonly brownish and crinoidal. Its thickness in this region is generally from 4 to 5 feet.

At scattered localities throughout its extent the basal part of the Floyds Knob member is conglomeratic and contains rounded pebbles of various types apparently derived from the older Borden formations.

The typical area of the Edwardsville formation extends from southern Floyd to northern Washington County. In this region the formation above the Floyds Knob member consists of a variable succession of fairly resistant sandstones alternating with softer, more shaly beds and ranges from 40 to 75 feet in thickness. The sandstones are fine-grained and lack the perfect bedding that characterizes the Locust Point and Carwood formations. They are more abundant in the upper part of the Edwardsville than in the lower, are light gray to buff or mottled, and are somewhat ferruginous. The lower part of the formation is mainly massive soft siltstone. The shaly beds that separate the sandstones vary from bluish and argillaceous to gray-

[9] The Floyds Knob was described as a formation of the Borden group occurring between the Carwood and Edwardsville formations (54, p. 76) but its thickness is distinctly out of line with the thicknesses of the other recognized Borden formations. It possesses no known faunal pecularities and its lithology is no more distinctive than certain other Borden beds. Its only claim to recognition as a distinct formation is its unusual persistence, and the writers do not believe that this is of sufficient importance to warrent its being given more than member rank.

drab-buff and are very sandy. Upon weathering the Edwardsville formations become light buff to yellowish mottled with light gray patches.

The Edwardsville formation thickens in northwestern Washington County. The upper part is more sandy than the lower, which, above the Floyds Knob member, is fairly uniform massive soft siltstone. In northern and eastern Washington County the formation attains a thickness of 75–160 feet. Just above the Floyds Knob member a fairly persistent thick bed or several thinner beds of sandstone with a brachiopod fauna and a maximum thickness of 15 feet has been named the Brownstone Hills member. Above this the lower half of the Edwardsville is mainly sandy shale which grades into the fairly massive siltstone of the upper part of the formation. Resistant sandstone beds are present in the upper half of the formation, particularly in its lower part, and one unusually prominent and persistent bed 3–5 feet thick, that occurs 60–65 feet below the top of the Edwardsville has been named the Dry Creek member.

The thickness of the Edwardsville formation continues to increase into Monroe and Brown counties. In Monroe and southern Morgan counties it reaches a thickness of 175–210 feet. Here the beds above the Floyds Knob member may be subdivided into three parts, the lowest of which is a complex succession of evenly bedded sandstones separated by shale. A well defined resistant sandstone generally $1\frac{1}{2}$–3 feet thick and occurring 5–10 feet above the Floyds Knob is known as the Cutright member. At various places and at different horizons in this lowest part of the Edwardsville there are bioherms (reef-like limestone deposits) which may be as much as 70 feet thick and 2 miles in diameter and are characterized by the fragmental remains of crinoids and bryozoans. Near the bioherms and elsewhere where the lowest Edwardsville is more or less calcareous, there occurs about 25 feet above the Floyds Knob member an irregular 4- to 8-foot zone of sandy material which weathers to an ocherous color, contains dark brittle calcareous patches, a few small geodes, and local chert nodules, and closely resembles the Floyds Knob member. This has been named the Weed Patch member. At a few places it is a gray to brown siliceous limestone bed and at one locality it is represented by fossiliferous sandstone. The Floyds Knob member can not be distinguished from the overlying beds at many places, particularly where bioherms extend nearly to the base of the Edwardsville or where, about the bioherm margins, the sediments consist of slightly calcareous brittle shale with chert nodules.

The middle part of the Edwardsville formation in Monroe and

southern Morgan counties is 50–110 feet thick and consists of siltstone, which is most argillaceous below and massive especially in the upper part, with a few harder sandstone layers. The uppermost part of the formation is variable in thickness and well bedded and consists of alternating resistant sandstones and soft shales. A very resistant dark yellowish brown sandstone mottled with gray, which is 1–4 feet thick and occurs 5–15 feet below the top of the formation, is known as the Mt. Ebel member. It has a brachiopod fauna.

The Edwardsville formation in most of Brown County is similar to that in Monroe County except that there are no prominent bioherms and the beds are more sandy. The Weed Patch member, described above, is more persistent here than farther west and commonly attains a thickness of 4–7 feet of calcareous sandy, ocherous material but is locally represented by fossiliferous sandstone.

In Warren and Fountain counties the Floyds Knob member is overlain by evenly stratified fine-grained blue-gray sandstone that weathers brownish and locally grades into sandy shale. These beds were formerly quarried extensively along Wabash River and have been termed Riverside sandstone from a village in Fountain County.

The Edwardsville formation becomes more calcareous and cherty from north to south in southern Floyd and southeastern Harrison counties, Indiana, and Jefferson, Hardin, and Bullitt counties, Kentucky. In the transition area, calcareous beds appear first at the top of the formation and then others come in at progressively lower horizons until the entire formation consists of yellowish siliceous brittle limestone, 55–60 feet thick, with much light gray to bluish chert which weathers buff, and more or less extensive purer crinoidal lenses. Small geodes are locally common. At some places the Floyds Knob member is represented by a bed of oölite but at others it is indistinguishable. A zone of greenish glauconitic clay less than 1 foot thick overlies the Floyds Knob member at several places in Indiana. Similar greenish clay occurs at the base of the Edwardsville formation in Jefferson County, Kentucky, where the oölitic Floyds Knob member is absent.

The cherty Edwardsville limestone in Jefferson and adjacent counties, Kentucky, has generally been referred to the Warsaw formation and the name West Point member has been proposed for it[10] (58, p. 281) but it has not been distinguished as a separate unit of the section farther south.

[10] The name West Point has priority of several weeks over Edwardsville but is abandoned in favor of the latter because of the much clearer stratigraphic relations of this formation in Indiana.

Middle Osage strata in Kentucky.—The middle Osage strata in Jefferson County, Kentucky, have been referred to the basal Warsaw limestone, the Holtsclaw sandstone, and the Rosewood shale but none of these divisions has been recognized in the section more than a few miles south of Ohio River, nor has the more acceptable Indiana succession of Edwardsville, Carwood, and Locust Point formations been traced beyond this same region. Farther south the Osage beds commonly have been separated into the New Providence shale below and the Fort Payne chert and Warsaw limestone above, but this arrangement is unsatisfactory because (1) the upper boundary of the New Providence is uncertain, (2) the middle division in Kentucky, which is exclusively Keokuk in age, is not equivalent to the true Fort Payne, which contains Burlington and Kinderhook beds as well as Keokuk, and (3) the proper dividing line between beds of Keokuk and Warsaw age is doubtful. It is probable that the Indiana formations will be recognized for some distance beyond Jefferson County in Kentucky, and until the limits of the useful application of these units are determined it seems inadvisable to propose new names for this part of the section which may be temporarily termed "middle Osage strata."[11]

The middle Osage strata along the southwestern border of the Kentucky Blue Grass region consist of dark gray unevenly laminated shale, which locally becomes greenish below, and irregular lenticular limestone layers that may be light-colored, massive, and crinoidal, or bluish gray, fine-grained, siliceous, and non-fossiliferous. Upon weathering the siliceous limestone layers are commonly transformed to brittle chert. Middle Osage strata apparently decrease in thickness south of Jefferson County. In Allen and Barren counties this part of the section consists of about 100 feet of mainly massive pure coarsely crystalline and crinoidal pinkish gray cherty limestone. The chert is most abundant in the upper beds where it occurs in numerous layers 3–4 inches thick and is light brown to milky white in color. In Allen and Barren counties geodes are less abundant in the lower part of the middle Osage strata than they are in the underlying beds that are referred to the New Providence but they are locally numerous in the upper part.

Warsaw formation.—The name Warsaw was originally given to

[11] Since this paper was submitted to the editor an important publication by Stockdale has appeared in which the lower Mississippian strata on the borders of the Lexington dome in Kentucky are described. The classification proposed therein consists of (1) New Providence shale at bases overlain successively by (2) Broad Lead formation (Locust Point plus Carwood of Indiana), (3) Floyds Knob formation, (4) Muldraugh formation (Edwardsville plus lower Harrodsburg of Indiana), (5) Harrodsburg (restricted) limestone, and (6) Salem limestone (54a, pp. 75–76).

18 feet of thin-bedded bluish gray limestone with interbedded calcareous shale which crops out at Warsaw in Hancock County, Illinois, (22, p. 193) but was soon expanded to include about 50 feet of strata lying between the geode beds and the St. Louis limestone (23, p. 97). Subsequently 8 feet of cross-bedded yellowish weathering limestone grading locally into calcareous sandstone which occurs immediately below the St. Louis limestone was removed from the Warsaw at its type locality and assigned to the Salem limestone (81, p. 163), and the geode beds, which had formerly been included in the Keokuk, were transferred to the Warsaw formation (6, p. 157; 67, p. 185). As the Warsaw formation thus defined was considered exactly equivalent to the Harrodsburg limestone of Indiana (6, p. 157; 16, p. 493) the latter name was abandoned because Warsaw had priority.

The lower division of the Warsaw formation, which at its type locality is about 36 feet thick and has been termed the "geode beds," consists of massive fine-grained earthy gray geode-bearing limestone below, a thin bed of locally brownish dolomitic cherty limestone in the middle, and bluish gray tough slightly calcareous geode-bearing shale above. At Keokuk, Iowa, this basal member of the Warsaw has thinned to less than 30 feet and it apparently pinches out entirely a short distance farther north. Shaly beds are more persistent southward, however, and dominate the lower part of the Warsaw as far south as Ste. Genevieve County, Missouri, and Monroe County, Illinois. In Calhoun County, Illinois, this zone is about 50 feet thick and consists of soft somewhat calcareous gray to greenish gray shale with interbedded layers of brownish argillaceous and somewhat dolomitic limestone, particularly in the upper and lower parts. Geodes are present. In Ste. Genevieve County, Missouri, and Monroe County, Illinois, the shaly lower Warsaw is also about 50 feet thick. It consists of bluish gray to buff shale with a variable number of limestone lenses.

Apparently the upper division of the Warsaw formation has not been distinguished from the overlying Salem everywhere in western Illinois and adjacent parts of Missouri. At Warsaw it reaches a thickness of nearly 40 feet and is composed of bluish gray shale with thin interbedded layers of argillaceous limestone, a few thin beds of fine-grained bluish gray sandstone, and several massive bluish gray dense to finely crystalline limestone strata which locally are irregularly and incompletely dolomitized. It thins northward and disappears from the section a short distance north of Keokuk. South of Warsaw this part of the formation becomes increasingly calcareous and has probably been included in the Salem or Spergen formation. In Ste. Genevieve County, Missouri, and Monroe County, Illinois, the upper

Warsaw consists of about 60 feet of gray to buff fine-grained more or less earthy and locally dolomitic limestone. It is nearly free from chert although a moderate amount is present in the lower part at some places. Near the top some beds are more crystalline than the other strata.

The Warsaw and Salem limestones have not been separated in southern Illinois and western Kentucky, where they attain a combined thickness of 200 to 250 feet. In Union County, Illinois, they consist of dominantly light-colored coarse-grained limestone, part of which may be oölitic. Dense bluish gray cherty layers occur in both the lower and upper parts of the formation. In Hardin County, Illinois, the lower three-fourths of this succession is mainly nearly black dense somewhat cherty limestone and the upper fourth, which may be Salem, is composed of light gray coarse-grained thick-bedded limestone with interbedded zones of darker shaly limestone and shale.

In Allen County, Kentucky, where the Salem limestone has not been recognized, about 100 feet of strata have been assigned to the Warsaw formation, the lower 20 feet of which consist of shaly limestone with interbedded coarsely crystalline layers and the remainder of bluish gray thin-bedded cherty limestone containing many geodes. In northern Hardin County, Kentucky, the Warsaw formation, including the few feet of limestone above the Somerset shale that may be equivalent to the Salem, reaches a maximum of about 220 feet. Because the Edwardsville formation of the Borden group has commonly been included in the Warsaw formation in Jefferson, Hardin, and adjoining counties, Kentucky, its reported thicknesses there are too great by 50 feet or more. It is uncertain to what extent similar errors have been made farther south along the margin of the Blue Grass region where the Warsaw formation consists of limestone and shale in variable proportions. The limestone is mostly gray to bluish gray, coarse-grained and crinoidal, and certain beds are notably cross-bedded. The shaly beds and partings are generally bluish gray and highly calcareous. A shaly zone with interbedded limestone layers, which is present in the upper part of the formation and attains a thickness of 20 to 50 feet, is correlated with the Somerset shale member of eastern Kentucky and may be equivalent to the shale underlying the Salem limestone in Indiana.

In Indiana the Warsaw limestone crops out continuously from Montgomery County to Ohio River, with a thickness of 60–90 feet. It is divisible into two parts, the upper of which consists of 30–50 feet of massive regularly bedded pure limestone of light gray to bluish

gray color which weathers nearly white. Much of it is crystalline and certain layers are very fossiliferous. It contains some chert. At the top is a layer 4–10 feet thick consisting almost entirely of comminuted bryozoans.

The lower part has been separated into three members, the lowest of which, named Ramp Creek from a stream in Monroe County, is variable. It consists of brittle shaly, more or less siliceous, and sandy yellow-weathering limestone with local and irregular crinoidal lenses and attains a total thickness of 17–28 feet. It contains abundant geodes and much chert. The Leesville or middle member, named from a village in Lawrence County, is a massive resistant crinoidal limestone layer $1\frac{1}{2}$–8 feet thick and commonly crops out as an overhanging ledge and produces many small waterfalls. The upper or Guthrie Creek member consists of 2–10 feet of shaly to siliceous buff-weathering geode-bearing limestone. Its name is taken from a stream in Lawrence County.

The Warsaw limestone overlies the Edwardsville formation conformably in Indiana. The contact is fairly sharp and easily recognized throughout most of its extent in Indiana, but near Ohio River and southward in Kentucky, where the Edwardsville consists largely of limestone, their division becomes much more difficult

OSAGE SEDIMENTATION

The almost complete transformation of the Osage group from a series of cherty limestones in the Mississippi valley to a series dominated by shales and sandstones in southwestern Indiana and the adjacent part of Kentucky is very striking. The records of deep wells indicate that this transformation occurs largely in the western part of the basin not far from the outcrop of these beds. In the oil fields of southeastern Illinois the Osage group consists of cherty limestone with shale at some horizons, and shaly zones also are present in an otherwise dominantly limestone Osage sequence in central Illinois.

On the east side of the Cincinnati arch, beds of Osage age make up the major portion of the Waverly series which resembles the Borden group of Indiana but contains more sandstone. In the southern part of the Appalachian region the Osage group is represented in the Fort Payne formation which, like the Osage beds of southern Illinois, is exceedingly cherty. These facts indicate that the clastic sediments were derived largely from the northern part of Appalachia, where evidently the land was much higher than it was in the southern part.

The Osage formations of Iowa give no indication of a near-by land area northwest of the Eastern Interior basin except during the final

Warsaw stage. Osage fossils are found in residual cherts widely scattered throughout the Ozark region and in weathered limestone boulders in the glacial drift of northern Illinois, giving evidence that the Osage sea spread far beyond the present outcrops of the group. However, the argillaceous content and red color of the Fern Glen formation in southwestern Illinois and the neighboring part of Missouri suggests that the Ozark region may not have been entirely submerged and perhaps was the source of some clastic sediment during early Osage time.

OSAGE PALEONTOLOGY

The faunas of the Osage formations are not sharply differentiated. They are, in reality, simply intergrading stages in a single slowly changing life succession. The Osage epoch was of sufficient duration that certain stocks underwent evolutionary changes, some old forms disappeared, and new ones were introduced. Large spiriferoids with high cardinal areas, such as *Syringothyris*, reached their culmination and other brachiopod forms attained unusually large size. *Leptaena analoga*, the last representative of an ancient stock, died out in early Burlington time. The *Spirifer grimesi-logani* gens which originated in Kinderhook time became conspicuous and abundant in the Burlington and Keokuk but did not continue later.

Some of the more typical species of the Fern Glen fauna are: *Cyathaxonia arcuata*, *Evactinopora sexradiata*, *Leptaena analoga*, *Dictyoclostus*[12] *fernglenensis*, *Productina sampsoni*, *Rhipidomella jerseyensis*, *Schizophoria poststriatula*, *Rhynchopora persinuata*, *Spirifer subtexta*, *Delthyris novamexicana*, *Spirifer rowleyi*, *Spirifer vernonensis*, *Brachythyris chouteauensis*, and *Cliothyridina glenparkensis*, although a number of these also occur in the lower part of the Burlington formation.

The Burlington limestone has been subdivided into a lower and an upper part largely on the basis of crinoids but these fossils are not sufficiently abundant or well enough preserved to be of much service except at scattered localities. Among the fossils restricted to the Burlington formation are *Cryptoblastus melo*, *Orbitremites norwoodi*, *Dictyoclostus burlingtonensis*, *Rhipidomella burlingtonensis*, *Camarophoria bisinuata*, *Spirifer grimesi*, *S. forbesi*, and *Spiriferella plena*. A number of older species which continued into Burlington but not

[12] Recent revision of the American Productidae has resulted in the removal of many species from *Productus* to several other genera including *Dictyoclostus*, *Echinoconchus*, *Linoproductus*, *Worthenella*, *Marginirugus*, and *Productina*. According to present interpretation the name *Productus* takes precedence over *Diaphragmus* and its use is now restricted to species formerly assigned to that genus.

into Keokuk time include *Leptaena analoga, Schizophoria swallovi,* and *Spirifer louisianensis.* New species which first appear in the Burlington but are also present in younger formations include *Triplophyllum dalei, Echinoconchus alternata, Brachythyris suborbicularis,* and *Reticularia pseudolineata.*

The Keokuk fauna contains bryozoans in much greater abundance and diversity than the Burlington fauna, and many new species appeared at this time. Two genera easily recognized and therefore particularly important are *Archimedes* and *Worthenopora.* Several new species of brachiopods developed in Keokuk time. The long-hinged *Spirifer logani,* which was apparently derived from the short-hinged *S. grimesi* of Burlington time and *S. rowleyi* of Fern Glen and early Burlington times, is characteristic of the Keokuk. *Dictyoclostus crawfordsvillensis,* which is confined to the upper part of the Keokuk formation, occurs in considerable numbers in Indiana, Kentucky, southern Illinois, and southeastern Missouri but is unknown north of St. Louis. *Spirifer logani, Orthotetes keokuk,* and *Tetracamera subtrigonia* are commonly associated with it. Species which first appeared in the Keokuk but continued into later epochs include *Orthotetes keokuk, Worthenella wortheni, Echinoconochus biseriata, Rhipidomella dubia, Camarotoechia mutata, Tetracamera subcuneata, Spirifer keokuk,* and *Eumetria verneuiliana.*

The paleontology of the Borden group in Indiana and Kentucky has never been studied systematically. The presence of numerous characteristic Mississippi Valley species shows the general equivalence of this group with the Osage group on the west but the great differences in environment in which the invertebrates lived on the two sides of the basin makes accurate correlation as yet impossible. The general equivalence of the New Providence to the Fern Glen is indicated by such diagnostic species as *Spirifer vernonensis, S. fernglenensis,* and *Ptychospira sexiplicata.* Equally characteristic Kinderhook species, such as *Schuchertella lens* and *Athyris hannibalensis,* are present in the New Providence, however, and were they definitely restricted to the lower part this might be assigned to the Kinderhook. In Indiana and Kentucky there is no such sharp faunal break between the Kinderhook and Osage faunas as there is in the Mississippi Valley and thus the situation is somewhat similar to that of the Waverly series of Ohio, where such characteristic Kinderhook forms as *Promacrus* occur at least as high as the basal Logan, which has been variously correlated with the middle New Providence and Carwood of the Borden group.

The New Providence fauna, however, also contains species such

as *Brachythyris suborbicularis* and *Echinoconchus alternata* which are not known below the Burlington limestone of the Mississippi Valley, as well as an assemblage of crinoids characteristic of lower Burlington beds, but no fossils restricted to the upper Burlington have ever been reported from Indiana or Kentucky. The Kenwood sandstone, which is considered to be the topmost member of the New Providence formation, has yielded specimens of *Worthenella wortheni* which is unknown below the Keokuk limestone in the Mississippi Valley.

The Locust Point formation is almost barren of fossils other than worm markings but the Carwood fauna is distinctly Keokuk in age and contains such diagnostic species as *Orthotetes koekuk*, *Worthenella wortheni*, and *Syringothyris textus*. The Edwardsville fauna is dominated by Keokuk species, including *Rhynchopora beecheri* and *Spirifer crawfordsvillensis* in addition to those already mentioned, but also contains a few forms, such as *Spirifer washingtonensis*, which are not known below the Warsaw formation in the Mississippi Valley. *Archimedes*, which first appears and is common in the Keokuk limestone of Illinois, Iowa, and Missouri, is rare in the Edwardsville formation of Indiana and Kentucky and unknown at lower horizons.

The Warsaw and Salem faunas have been carefully studied and are well known. *Marginirugus magnus*, one of the largest American species of the Productidae, is restricted to an important zone in the upper part of the Keokuk and the lower part of the Warsaw formations. It is not known north of St. Louis but to the south and east it is widely distributed and locally extremely abundant. In association with it commonly occur *Syringothyris subcuspidatus*, *Spirifer washingtonensis*, and *Aviculopecten amplus*. *Brachythyris subcardiformis* has been reported from the Keokuk formation in Iowa but is not known to occur beneath the Warsaw formation in the Eastern Interior basin. The uncommon but very characteristic *Spirifer lateralis* is associated with this species in the Warsaw and Salem faunas.

Numerous new species appear in the Warsaw formation and practically all of the forms common in it occur also in the Salem formation. Among the more typical fossils that are confined to these formations are *Metablastus wortheni*, *Pentremites conoideus*, *Talarocrinus* (?) *simplex*, and *Archimedes wortheni*. Other common forms which survived into Chester time are *Dielasma inflatum*, *Girtyella indianensis*, *G. turgida*, and the typical form of *Composita trinuclea*. *Spirifer keokuk* is largely replaced in the Warsaw by the very closely related *S. bifurcatus*.

OSAGE-MERAMEC RELATIONS

The Osage group as characterized by the Burlington and Keokuk limestones and the Meramec group as typified by the St. Louis and

Ste. Genevieve are stratigraphic divisions easily distinguished by both paleontologic and lithographic characters throughout an extremely large area in the states east of the Mississippi River. Between these characteristic Osage and Meramec formations occur the Warsaw and Salem limestones, which are transitional beds, and the selection of a definite line of division is difficult and subject to much difference of opinion. At the present time this line is drawn by most geologists at the base but by some others at the top of the Warsaw, and the Illinois State Geological Survey has for some years followed the latter practice.

The Warsaw and Salem formations as now generally recognized are undoubtedly very closely related. Practically all of the common Warsaw fossils are known to occur in the typical Salem limestone of Indiana, and the latter formation is identified mainly by its oölitic character and a peculiar fauna in which small molluscs are conspicuous. The writers believe that neither the typical Salem lithology nor its peculiar fauna are of precise time significance but are reflections of more or less local environment conditions that prevailed in different areas at different times. Both are conspicuous in the Short Creek oölite of southwestern Missouri, which occurs in the basal part of the Warsaw formation, and in the so-called Salem limestone of Ste. Genevieve County, Missouri, whose upper part carries *Lithostrotion* and is therefore presumably of lower St. Louis age. Oölite carrying very similar molluscan faunas occurs in the Ste. Genevieve limestone, at several horizons in the Chester series, and even well up in the Pennsylvanian system of the Mid-Continent area.

Considerable difficulty and much uncertainty attends the identification of the Warsaw-Salem boundary wherever these beds crop out except in the Indiana area where the typical Salem limestone is developed, and nowhere else has the Salem formation been satisfactorily delimited. In western Kentucky and southern Illinois, Salem beds have not been differentiated and if they are present they have been included with the underlying Warsaw. In the Mississippi Valley area north of St. Louis there is strong reason to believe that the current Warsaw-Salem boundary, determined on the basis of a lithologic change no more significant than that which separates the Warsaw formation into lower and upper parts, is not drawn at an even approximately uniform horizon.

Under these circumstances the writers believe that the selection of the Warsaw-Salem boundary to separate the Osage and Meramec groups was unfortunate. They likewise believe that the restriction of the Warsaw formation, originally defined as including the beds between the Keokuk and St. Louis limestones, and the recognition

of the Salem formation in the Mississippi Valley was ill-advised. In their opinion the stratigraphic and paleontologic situation is best expressed by considering the Salem and underlying Harrodsburg limestones of Indiana as members of the Warsaw formation (72). With this interpretation (1) the name Warsaw would again be applied, as originally, to all beds between the Keokuk and St. Louis limestones, (2) it would be unnecessary to attempt to identify the Salem limestone in areas where its typical lithology is not developed, (3) the re-expanded Warsaw could be locally subdivided into members wherever desirable, (4) where warranted by lithology or other evidence the upper member would be correlated with the Salem limestone of Indiana, and (5) the Warsaw-St. Louis boundary would be the only alternative to the Keokuk-Warsaw boundary as the dividing line between the Osage and Meramec groups.

The Salem limestone is almost universally conceded to be a member of the Meramec group. Evidence concerning the proper disposition of the Warsaw is, however, conflicting. The facts that the limestone layers in the Warsaw formation are more or less granular, thus resembling those of the underlying Osage limestones rather than the dense limestone of the St. Louis, and that west of Mississippi River Warsaw strata are practically co-extensive with the underlying Burlington-Keokuk limestones rather than the more restricted St. Louis-Ste. Genevieve limestones[13] suggest that this formation should be included in the Osage group. The Warsaw fauna, which resembles the Keokuk fauna in many respects, has likewise been cited as evidence of the Osage age of this formation, but numerous new species appear in the Warsaw and, as previously noted, most of the common Warsaw species occur in the Salem limestone where the ***Pentremites-Composita*** fauna, so characteristic of all subsequent Mississippian formations, first becomes conspicuous. Furthermore the regional calcareous versus clastic composition of the Warsaw formation follows that of the overlying St. Louis and Ste. Genevieve limestones rather than the underlying Burlington and Keokuk limestones, as is discussed more fully elsewhere.

The writers believe that the Osage and Meramec groups should be separated at the boundary between the Keokuk and Warsaw forma-

[13] The recent discovery of limestone containing *Lithostrotion* (E. L. Clark, "The St. Louis Formation in Southwestern Missouri," *Mo. Geol. Surv.*, biennial report, 1937) and the occurrence of limestone of typical St. Louis lithology in the subsurface of northwestern Missouri (H. S. McQueen and F. C. Greene, "The Geology of Northwestern Missouri," *Mo. Geol. Surv.*, ser. 2, vol. 25, p. 31, 1938) has been brought to the writers' notice by H. A. Buehler. These occurrences prove conclusively that the Meramec sea was not as restricted to the west as was formerly supposed and consequently the argument presented above loses much of its force.

tions because they consider the very close relations of the Warsaw and Salem formations, as they are now commonly recognized, and the appearance of new species, including the characteristic *Pentremites-Composita* fauna, to be of more importance than the presence of many hold-over Keokuk species, and because they regard the continental physiographic changes, inferred from the regional sedimentological similarity of the Warsaw to characteristic Meramec rather than to characteristic Osage beds, to be of greater significance than the similarity in extent of the Warsaw sea in the Mid-Continent area to the preceding Osage rather than to the later Meramec seas.

MERAMEC GROUP

The Meramec group, named from Meramec River in Missouri, includes, according to the classification followed by the Illinois State Geological Survey, the Salem, St. Louis, and Ste. Genevieve limestones. As stated, the authors believe that the lower boundary of the group as thus defined is unsatisfactory and favor the inclusion also of the Warsaw formation.

Salem limestone.—Two names, Salem and Spergen, both taken from localities in Washington County, Indiana, have been applied to the limestone formation from which the famous Bedford, Indiana, building stone is obtained. The name Salem, which was proposed first and which has been used consistently by the Indiana Geological Survey for 30 years, is preferable to the name Spergen in spite of the fact that the latter has been adopted by the United States Geological Survey.

The Salem is characterized by massive cross-bedded light gray granular limestone composed almost entirely of fragments of fossils, the tests of foraminifera, and oölites. In its typical development in Indiana the Salem limestone is lenticular. It attains a thickness of 50–60 feet near Bedford but locally pinches out entirely. Layers of buff to nearly black bituminous calcareous shale are associated with the massive limestone, particularly at the top and bottom, and including these beds the formation reaches a maximum thickness of 90–100 feet. The same type of shale is present below the massive oölitic limestone throughout most of its extent in Indiana. Southward it becomes lighter in color and less bituminous and in Kentucky consists of 20 feet or less of shaly limestone or calcareous shale with interbedded layers of highly fossiliferous limestone which has been correlated with the Somerset shale member of the Warsaw formation in eastern Kentucky. Above this shale member south of Ohio River locally occurs a few feet of limestone which is stratigraphically equivalent

to the typical Salem limestone but lithologically indistinguishable from the Harrodsburg. This limestone has not been reported more than a few miles south of Ohio River.

In western Kentucky the Salem limestone, if present, has not been distinguished generally from the underlying Warsaw. Near Princeton, however, 40–50 feet of strata underlying the St. Louis limestone have been referred to the Salem. These beds were originally very pure limestone made up almost entirely of fragmental organic material but are now completely silicified although not changed to true chert.

In Hardin County, Illinois, the upper 60 feet or so of the "Warsaw" limestone may be equivalent to the Salem. They consist of light gray coarse-grained thick-bedded limestone with interbedded zones of darker shaly limestone and shale. In Union County, Illinois, the 200–250 feet of light-colored coarse-grained partly oölitic "Warsaw-Salem" limestone has not been subdivided.

In Ste. Genevieve County, Missouri, 160 feet of gray to white more or less oölitic limestone have been referred to the Salem, but paleontologic evidence strongly suggests that the upper part of these beds is actually of St. Louis age. The central 100 feet is an exceptionally pure oölite and is the basis of an important high-calcium lime industry. Northward the Salem limestone becomes progressively less pure. Oölite is present at Meramec Highlands west of St. Louis and near Alton, Illinois, but beyond this the formation as recognized consists mainly of earthy limestone with minor shaly and sandy beds.

At Warsaw, Illinois, beds referred to the Salem consist of 4–8 feet of more or less cross-bedded yellowish limestone that grade laterally into calcareous sandstone, which has been termed Sonora sandstone (27, p. 320). Apparently equivalent beds in southeastern Iowa attain a maximum thickness of nearly 30 feet, show a variable succession of cross-bedded crinoidal limestone, massive brown dolomitic limestone, brownish arenaceous dolomite, fine-grained bluish sandstone, and various types of shale which changes greatly from place to place, seem to overlie the subjacent Warsaw formation unconformably, and extend some distance beyond the limits of these beds. The name Belfast beds has been proposed for the Salem formation in Iowa (67, p. 214).[14]

Because the upper division of the Warsaw is similar to the overlying Salem beds and not easily separated from them, south of Warsaw the boundary between the two formations has been drawn at a horizon that more or less sharply separates a lower dominantly shaly zone (the lower division of the Warsaw) from an upper zone consisting of hard, massive to thin-bedded, granular to fine-grained, more or less

[14] This name has been previously used for a Silurian formation in Ohio.

earthy, impure and dolomitic limestone beds separated by layers or partings of shale that are commonly calcareous. The resulting "Salem" beds reach an average thickness of 60 feet in the area between Quincy and Alton, Illinois, although they may be considerably thicker locally. In Adams County, Illinois, a possible unconformity marked by basal conglomerate occurs in the midst of these beds and may be equivalent to the unconformity which occurs beneath the Salem in southeastern Iowa. In central Pike County, Illinois, Salem beds are reported to overlap older strata and rest on Burlington limestone (14, p. 93).

St. Louis limestone.—The St. Louis limestone was named from the city of St. Louis, Missouri, because of the many excellent exposures of the formation in that vicinity.

In southeastern Iowa the St. Louis is separated into two members, the Croton below and the Verdi above, both named from towns in Washington County. The Croton member consists of about 30 feet of compact buff dolomitic limestone which grades into or is interbedded with dense gray nondolomitic limestone. The Verdi member consists of a maximum of 35 feet of dense gray limestone which grades locally into fine sandstone. Both members are locally brecciated. The Croton member overlies older Mississippian strata unconformably and overlaps formations as low as the Kinderhook. It is separated from the Verdi member by another unconformity that is said to be recognizable as far south as Alton, Illinois (67, p. 231).

In western Illinois and northeastern Missouri the St. Louis limestone has not been separated from overlying beds that may be Ste. Genevieve in age. In Adams and Hancock counties, Illinois, and Lewis and Clark counties, Missouri, the lower 10–30 feet of St. Louis limestone is brecciated and conglomeratic, and the basal 2 or 3 feet is a nodular layer of dense crenulated limestone similar to that under the brecciated zones in Iowa. The brecciated horizon is less conspicuous to the south and is not present at the base of the formation in or beyond Lincoln County, Missouri. Above the brecciated layer the St. Louis formation is light gray dense, almost lithographic limestone in even layers locally separated by greenish calcareous shale. Local brownish dolomitic layers and more rarely sand lenses occur a short distance above the brecciated zone. Nodules and layers of chert are abundant. In Lewis and Clark counties, Missouri, the St. Louis is 40–60 feet thick. The upper part contains oölitic layers and a local sandstone as much as 6 feet thick and may represent the Ste. Genevieve formation. Farther south the St. Louis limestone is much thicker. At Alton, Illinois, it has been estimated to be 270 feet thick, and at

St. Louis its average thickness is said to be 325 feet, possibly including beds of Ste. Genevieve age. Still farther south, in Ste. Genevieve County, Missouri, beds assigned to the St. Louis limestone are 100–160 feet thick, but it is probable that a considerable portion of the 160 feet of oölitic limestone that has been referred to the Salem, an unprecedented thickness for that formation, is actually of lower St. Louis age. Throughout this area and also in Monroe County, Illinois, the St. Louis is mainly a compact dense gray limestone which breaks with a conchoidal fracture. Brownish dolomitic layers and beds of crystalline limestone occur locally, but shaly strata are few. Chert is common but not as abundant as in the Burlington and Keokuk formations. The St. Louis limestone is well and evenly stratified except where cross-bedded or brecciated. In southern Calhoun and Jersey counties, Illinois, there are several brecciated zones and a particularly conspicuous one occurs about 120 feet above the base of the formation at Alton. Similar zones have not been reported farther south. In southern Calhoun County beds of sandy oölite occur in both the lower and upper parts of the formation; possibly the upper oölitic beds should be referred to the St. Genevieve limestone.

The St. Louis limestone in Union County, Illinois, has an estimated thickness of 350–400 feet. The lower 25–30 feet is dense, dark gray, and siliceous; the middle part is dark gray and medium-grained with some interbedded coarser-textured strata; and the upper part is dark bluish gray and very dense with subordinate gray finely granular layers. Chert is abundant throughout the formation but is associated mainly with the denser strata.

In Hardin County, Illinois, and the neighboring portion of western Kentucky, the St. Louis is a dense fine-grained limestone with some granular and a few coarsely crystalline layers. The upper 75–100 feet is gray to bluish gray and the remainder is dark, nearly black limestone. Chert is common throughout and occurs mainly as irregular masses distributed parallel with the bedding. Some oölite occurs in the lower part of the formation near the Caldwell-Lyon county line southwest of Princeton, Kentucky. A deep well drilled near Princeton penetrated at least 300 and possibly more than 400 feet of St. Louis limestone.

Near Bowling Green in Warren County, Kentucky, the thickness of the St. Louis limestone penetrated in numerous oil wells is estimated at about 300 feet. At its outcrops in Barren and Warren counties the upper part of the formation is composed of dense gray limestone with some coarsely crystalline and some brownish lithographic layers; the middle part contains gray fine-grained closely banded

strata; and the lower part is characterized by black finely crystalline bituminous limestone with which are associated light gray to buff earthy dolomitic layers. The formation is cherty throughout but no oölite has been observed in this region.

The St. Louis limestone thins northward and probably does not exceed 300 feet anywhere in Hardin County, Kentucky. It consists of fine-grained gray to nearly black cherty limestone with some lithographic layers and some earthy siliceous geodiferous layers. The geode beds occur in the lower part of the formation as far as Rock Haven but have not been observed elsewhere. Lithographic stone has been commercially quarried near Brandenburg in Meade County, Kentucky.

In Indiana the St. Louis formation constitutes the lower part of the Mitchell limestone up to and including the Lost River chert member. The Mitchell limestone, which is named from a town in Lawrence County, includes the St. Louis, Ste. Genevieve, and Paoli (lower Chester) limestones. The St. Louis is mainly a dense sublithographic thin-bedded cherty limestone with interbedded shales, particularly in the lower 40 feet. The total thickness of the Mitchell is reported to be 200 feet in Monroe County but increases to 300 feet or more near Ohio River.

The St. Louis limestone weathers to a cavernous condition and its zone of outcrop is generally marked by many sink-holes. Although there is everywhere a more or less sharp change in lithology at the base of the St. Louis limestone, this formation succeeds the underlying beds conformably except along the northwestern border of the Eastern Interior basin. The St. Louis limestone passes more gradually into the overlying Ste. Genevieve and is conformable with it except along the western margin of the basin.

Ste. Genevieve limestone.—The Ste. Genevieve formation is typically exposed in the Mississippi River bluffs near Ste. Genevieve, Missouri. It is reported to be represented in the bluffs at Alton, Illinois, by 50 feet of fine calcareous sandstone but has not been certainly recognized farther north in Illinois. In southeastern Iowa the Verdi member of the St. Louis formation is overlain unconformably by the Pella beds of Ste. Genevieve age, named from a town in Marion County. The Pella beds consist of a thin basal sandstone, overlain by 5 feet of shale and 25 feet of compact thin-bedded limestone which grades into shale to the northwest.

In its typical area the Ste. Genevieve is a dark to light gray limestone which overlies the St. Louis unconformably at some places. A basal conglomerate contains limestone and chert pebbles and in Perry

County, Missouri, silicified Devonian fossils. At many places the lower beds are oölitic, arenaceous, and cross-bedded; higher strata are more regular and include a conspicuous band of reddish chert; and shaly beds, which are locally reddish, purplish, or greenish, and lenticular beds of fine-grained brown sandstone occur in the upper part of the formation at a few places. The thickness of the formation varies greatly from place to place as a result of pre-Chester erosion but may reach a maximum of 100 feet. Near Lithium in Perry County; Missouri, there is only 20 feet of Ste. Genevieve and the entire formation has been eroded from a considerable area in Monroe County, Illinois.

The Ste. Genevieve formation is about 300 feet thick in Union County, Illinois, and in Hardin County, Illinois, and in the neighboring portion of western Kentucky it averages about 250 feet with a maximum thickness of 320 feet penetrated by a well drilled near Princeton. It consists mainly of dense granular limestone in massive beds, some of which are oölitic and cross-bedded. Chert is not so abundant as in the underlying St. Louis limestone.

In the fluorspar district of southeastern Illinois and western Kentucky the Ste. Genevieve is divisible into three members: the Fredonia limestone, named from a village in Caldwell County, Kentucky; the Rosiclare sandstone, named from a mining town in Hardin County, Illinois; and the Levias (formerly Lower Ohara) limestone at the top, named from a village in Crittenden County, Kentucky (61, p. 439). The Fredonia limestone member includes the greater part of the formation. The Rosiclare is a brownish fine-grained calcareous sandstone 2 to 30 feet thick. It is not certainly known west of Pope County, Illinois, nor east of Cerulean Springs, Trigg County, Kentucky. Owing to pre-Chester erosion, the thickness of the Levias member ranges from 0 to 50 feet.

The thickest outcropping section of the Ste. Genevieve occurs in Union County, Illinois. A fine-grained calcareous sandstone 2–10 feet thick occurring 175 to 200 feet above the base of the Ste. Genevieve may represent the Rosiclare member. It is overlain by 30–40 feet of gray, granular, oölitic limestone, shaly in the upper part, that is probably the Levias member. This is succeeded by 50–80 feet of calcareous sandstone, limestone, oölite, and shale, some of which is red—these are believed to be the youngest Ste. Genevieve beds exposed anywhere in the Eastern Interior basin and for them the name Hoffner member is proposed as some of the best exposures of these beds occur near Hoffner School 7 miles southeast of Anna.

East of the fluorspar district in Kentucky the Ste. Genevieve

maintains a relatively constant thickness that is estimated at 180 feet in Edmonson County and 160 feet in Breckenridge County. The whole formation is similar to the Fredonia member farther west in Kentucky.

In Indiana the Ste. Genevieve limestone is represented by the middle part of the Mitchell limestone, above the Lost River chert. It is similar in color to the underlying St. Louis but is commonly oölitic and more heavily bedded.

The Ste. Genevieve is a cavernous limestone and like the St. Louis its presence is responsible for the development of large areas of karst topography. The lower passages of Mammoth Cave in Kentucky have been dissolved in the Ste. Genevieve limestone. Although it is not a notably cherty formation, numerous beds and irregular masses of chert do occur in it, particularly in the lower part, and chert is conspicuous in the residual soil derived from the Ste. Genevieve.

Except along the western margin of the basin the Ste. Genevieve succeeds the St. Louis conformably. At most places no sharp line of division can be drawn between these formations and it is common practice to place it more or less arbitrarily below the lowest prominent oölitic beds.

MERAMEC SEDIMENTATION

The Meramec group is the most uniformly calcareous and least clastic larger division of the Mississippian system in the Eastern Interior basin. At the close of the Keokuk epoch, as a result of either subsidence or erosion northern Appalachia no longer provided abundant sediment of the type that forms the greater part of the Borden group in Indiana. In the northwestern part of the Eastern Interior basin, however, clastic beds constitute an important part of the Meramec group and indicate the presence of a land area in that direction. The pre-Warsaw-Osage sediments of the upper Mississippi Valley yield little evidence of clastic material derived from the northwest and it is probable, therefore, that uplift occurred in this direction at the close of Keokuk time. This land area situated northwest of the Eastern Interior basin, however, was by no means as important a contributor of sediments during Meramec time as was northern Appalachia during Osage time.

MERAMEC PALEONTOLOGY

Practically all of the common Warsaw species are present in the Salem fauna but in addition there occurs a considerable variety of small molluscs which appear to be restricted to an oölitic limestone environment. These species, commonly associated with large numbers

of *Endothyra baileyi*, are indicative of certain special ecological conditions and are of no value for precise correlation. The assemblage first appears in the Short Creek oölite, which is the basal member of the Warsaw formation in southwestern Missouri, recurs in the Salem limestone of Indiana, in the so-called Salem near Ste. Genevieve, Missouri, which is probably in part of lower St. Louis age, and in the Ste. Genevieve limestone at various places. Very similar forms occur at several horizons in the Chester and even well up in the Pennsylvanian.

Although the St. Louis and Ste. Genevieve limestones are abundantly fossiliferous at many localities, it is so difficult to obtain identifiable specimens from these hard limestones that their faunas are the least adequately known in the entire Mississippian system, and no comprehensive and reliable list of species has ever been compiled for either of these formations. The faunas are too poorly known even to determine the upper limits of many Warsaw species. However, certain restricted species in the St. Louis and Ste. Genevieve are sufficiently abundant and conspicuous to identify certain faunal zones over wide areas. One of these, approximately equivalent to the St. Louis limestone, is marked by *Lithostrotion canadense*, an easily identifiable coral which is widely distributed and locally occurs abundantly in large colonies. It is readily silicified and is a common constituent of the St. Louis residuum. This species has never been observed anywhere in the Ste. Genevieve formation or in the Salem limestone of Indiana, and its occurrence, therefore, in beds near Ste. Genevieve, Missouri, which have been referred to the Salem on account of their lithology and molluscan fauna, suggests that these beds are at least in part of St. Louis age. A related form, *Lithostrotion proliferum*, has approximately the same range. It is unknown below the St. Louis formation but has been collected from beds referred to the base of the Ste. Genevieve in western Kentucky.

Platycrinus penicillus, a species of crinoid recognized by the small oval stem plates edged with spines, is of great importance in those regions where the lower formations of the Chester series consist of limestone, because it is widely present in the Ste. Genevieve limestone but has never been found in the Chester. This species also occurs in the St. Louis, however, and similar stem segments are present in the Salem limestone of Indiana. *Pugnoides ottumwa* which is locally abundant in Iowa but much rarer to the southeast occurs in the Fredonia, Levias, and Hoffner members of the Ste. Genevieve and is restricted to this formation. The compound coral *Lithostrotion harmodites* is conspicuous in parts of Kentucky, and in the western part of

the state it is restricted to a zone in the upper part of the Fredonia member.

The *Spirifer keokuk* gens continues throughout the Meramec group and is represented by the very closely related *S. bifurcatus* in the Salem, *S. littoni* in the St. Louis, and *S. pellaensis* in the Ste. Genevieve. This genus persisted into early Pennsylvanian time.

A few of the most common and characteristic Chester species, among which is *Productus elegans*, first appear in the Ste. Genevieve limestone but none of them is abundant.

MERAMEC-CHESTER RELATIONS

The unconformity which separates the Meramec group and the Chester series is the most important stratigraphic break within the Mississippian system in the Eastern Interior basin. It is not only actually exposed as an uneven contact between Meramec and Chester strata, but it is also demonstrated by local breccia and conglomerate beds in the basal Chester strata, by variation in thickness and absence of the upper members or all of the Ste. Genevieve formation within comparatively short distances, by overlap of Chester formations on older beds, by local variation in thickness of the basal Chester formations, and by other evidence.

In Ste. Genevieve and Perry counties, Missouri, the Ste. Genevieve limestone ranges in thickness from 20 to 100 feet or more. In Monroe County, Illinois, from T. 4 S., to T. 2 S., the basal Chester beds lie on the St. Louis limestone, the Ste. Genevieve limestone being absent except in the asymmetrical syncline which lies just west of the Waterloo anticline, although it is present both to the north in St. Clair County and to the south near the Randolph County line. In Secs. 5 and 8, T. 3 S., R. 9 W., southeast of Waterloo, Illinois, a hill of St. Louis limestone is bounded on three sides by the Aux Vases (basal Chester) sandstone. In the Mississippi River bluffs between Prairie du Rocher and Modoc, Randolph County, Illinois, the contact between the Ste. Genevieve limestone[15] and the Aux Vases sandstone dips more steeply than the limestone so that a number of the limestone beds are truncated. A conglomerate 2–3 feet thick is generally present at the base of the Aux Vases sandstone from Rock House Creek south for seven miles in Monroe County, Illinois, and also in the Mississippi River bluffs half a mile southeast of McBride in Perry County, Missouri. The chert pebbles in the conglomerate are identical with those derived from the St. Louis and Ste. Genevieve limestones and

[15] Recent observations indicate that these beds, referred to the Ste. Genevieve because of their oölitic nature, actually occur in the midst of the St. Louis limestone.

occurring along the present streams in this region. This indicates that these formations were thoroughly lithified and the nodular masses and beds of chert were developed in them before the beginning of Chester time.

Along a belt extending in Illinois from Sec. 30, T. 3 S., R. 9 W., south to the Monroe-Randolph county line the Renault formation, which overlies the Aux Vases sandstone unconformably and locally possesses a well developed basal conglomerate, overlaps both the Aux Vases sandstone and Ste. Genevieve limestone and comes to rest on the St. Louis. In Union County, Illinois, the Aux Vases sandstone is absent and the Renault formation lies on the Hoffner member of the Ste. Genevieve. The basal bed of the Renault is a nodular limestone, conglomeratic in appearance, and contains irregular masses of fine-grained sandstone and fragments of greenish shale.

In Hardin County, Illinois, the unconformable contact of the Shetlerville member of the Renault formation on the Ste. Genevieve limestone is well exhibited at Fairview Bluff above the railroad incline to a mine and also in the Ohio River bluff between Shetlerville and Wallace Branch, where a basal limestone conglomerate is present. A similar basal conglomerate 1 or 2 feet thick containing angular limestone pebbles up to 2 inches in diameter occurs at the base of the Renault at Cedar Bluff near Princeton, Caldwell County, Kentucky, and along the west side of Tow Hill and at Bissell Bluff northeast of Smithland in Livingston County, Kentucky. The Levias member of the Ste. Genevieve formation varies in thickness and is locally absent, as at a short distance northeast of Hampton and at Tow Hill, in Livingston County, and at several places northwest of Marion in Crittenden County, Kentucky.

In Warren and Edmonson counties, Kentucky, the exact contact of the Renault and Ste. Genevieve limestones has not been observed. The total thickness of the Girkin limestone (Renault and Paint Creek where the Bethel sandstone is absent), however, varies considerably, doubtless owing to the irregular upper surface of the Ste. Genevieve limestone on which it was deposited. Three or four miles west of Bowling Green this limestone is about 200 feet thick but only a few miles east it averages about 120 feet in thickness.

A basal conglomerate in the Renault formation has also been observed in a quarry on the Louisville, Henderson, and St. Louis Railroad, about one mile south of Sinking Creek in Breckenridge County, Kentucky, as well as at several other places in the same vicinity.

Although rarely exposed, the unconformity between the Ste. Genevieve and Paoli (lowest Chester) limestones in Indiana may be

TABLE

VARIATION IN THICKNESS OF CHESTER FORMATIONS. FIGURES IN ITALICS INDICATE AVERAGE OR COMMON DEVELOPMENT OF FORMATIONS

Name of Formation	*Dominant Character*	*Monroe, Randolph Counties, Illinois*	*Campbell Hill Quadrangle, Illinois*	*SE. Perry County, Missouri*	*Alto Pass Quadrangle, Illinois*	*Dongola Quadrangle, Illinois*	*Johnson County, Illinois*	*Pope County, Illinois*	*Hardin County, Illinois*	*Golconda Quadrangle, Kentucky*	*Cave in Rock Quadrangle, Kentucky*	*Smithland Quadrangle Kentucky*	*Eddyville Quadrangle, Kentucky*	*Princeton Quadrangle, Kentucky*	*Dawson Springs Quadrangle, Kentucky*	*Edmonson and Warren Counties, Kentucky*	*Meade and Breckenridge Counties, Kentucky*	*Indiana*
Kinkaid	Mainly limestone		90		0–50	?–50	?–140	?–150	?–100	?–200	0–125	?–160		100	100			0–20, *7*[j] 15–40, *28*
Degonia	Sandstone		70–150		0–75	60–80	100	0–?	50–60	20–50	20	10–20		20–30	20			0–35, *10*
Clore	Mainly shale	60	40–70, *55*		20–40	10–40, *30*	40	?–40	25–30	30–60	25	?–40		30–60	50			10–35, *25*
Palestine	Sandstone	60–80	25–60, *45*		30	40–50	40–?, *60*	?–80, *60*	60–100	60	60	40–60	*50*	40–60	60–100	0–160[g]	30–274[i]	0–25, *5*
Menard	Mainly limestone	60–80			70–90	70–90	?–100	?–100	80–120[f]	80–100	100–140	80–100	100	?–140	55–80			15–45, *30*[k] 0–20, *4* 20–45, *30*
Waltersburg	Sandstone				20–40	30–40	0–?	?–70		30–40	20	20–35		6–20	0–3			0–40, *20*
Vienna	Shale and limestone	60–75[a]		?–30	20–30	30–40	*60*	40–70, *60*		30	30–40	35	30	50	12–40			0–125, *60*
Tar Springs	Sandstone			75–90	75	50–70	40–100, *80*	100–150	100–150	100–150	100–160?	?–120	?–100	200	?–200	0–30	5–50	0–90, *45*
Glen Dean	Mainly limestone		Ste. Genevieve and N. Perry Co. Missouri	75–90	30–40	60–80	40–75, *60*	*60*	50–70	60–80	50–60	60	60	?–90, *40*	40–80, *50*	30–70, *60*	40–90	0–40, *15*[l] 15–40, *15*
Hardinsburg	Sandstone	200[b]		0	20–40	?–50, *30*	30–100, *60*	80–100	75–100	100	100–140	100–120	?–100	20–60	40–60	30–40	20–35	25–45
Golconda	Mainly limestone		100–200	60–80	40–60	100–130	40–150	150	140	80–175	80–100	75–170	70	30–80	40–70	20–40, *35*	30–50	10–40[m] 15–25
Cypress	Sandstone	30–75[c]	0	0	30–50	60–120	80–100	80–100	80–110	100–125	*100*	100	*80*	30–40	25–40	40–75, *60*	40–70	30–45
Paint Creek	Mainly shale	60	50			30–50, *35*	?–60	35–60	40–50	20–40	20–40	0?–20	20	100	100	80–200[h]	60–90	10–30[n] 10–40 1–10
Bethel	Sandstone	10–20[d]	5–10[d]	80[e]	30–60[e]	?–12	0–30	0–130	50–60	60–100, *70*	*40*	?–120, *100*	40–75	25–40	30–40	0	5–40	20–30
Renault	Shale and limestone	20–60	45–90			70–90	50–60	60	75–90	60–100, *75*	20–100, *75*	80	40–80	60–100, *80*			60–70	5–20[o] 10–30 20–50
Aux Vases	Sandstone	0–100	40–60	55–105	0	0	0	0	0	0	0	0	0	0		0	0	0

[a] Baldwin formation. [b] Okaw formation. [c] Ruma formation. [d] Yankeetown chert. [e] Renault and Paint Creek formations. [f] Waltersburg and Vienna formations included in Menard. [g] Leitchfield formation. [h] Girkin formation (Renault and Paint Creek limestones). [i] Buffalo Wallow formation. [j] Negli Creek limestone and underlying shale. [k] Siberia limestone and over- and underlying shales. [l] Glen Dean limestone and overlying shale. [m] Golconda and Indian Springs formations. [n] Reelsville, Elwren, and Beech Creek formations. [o] Paoli, Mooretown, and Beaver Bend formations.

seen in a railroad tunnel about $1\frac{1}{2}$ miles east of Depauw in Henderson County. This contact is commonly marked in Indiana by a brecciated or conglomeratic zone a few inches to several feet in thickness and at a few places is sharply defined and undulatory.

CHESTER SERIES

The Chester series is named from the city of Chester in Randolph County, Illinois. The section present in southwestern Illinois, however, is not typical of the series as a whole and the standard section has been built up mainly from studies conducted in Hardin County, Illinois, and adjacent portions of Illinois and Kentucky. No outcrops of Chester strata occur along Mississippi River north of East St. Louis, although they are present beneath the Pennsylvanian system in the Eastern Interior basin as far north as Macon County, Illinois. The northernmost outcrops of the Chester in Indiana occur in Putnam County, beyond which the series is completely overlapped by the Pennsylvanian system. South of these localities, however, the Chester formations crop out in a continuous band of varying width that outlines the Eastern Interior coal field.

The Chester series consists of a succession of alternating sandstone and limestone-shale formations of variable thickness and lithology (Table 1), none of which possesses physical characters by which it may be certainly identified over long distances. The sandstones resemble each other more closely than do the limestone-shale formations. They are all fine-grained, more or less micaceous, commonly iron-stained, and vary locally from massive to thin-bedded or shaly. With few exceptions, they can be identified only by their relations to the underlying and overlying formations. The sandstones generally rest unconformably on underlying beds.

The proportions of limestone and shale in the other formations vary greatly both laterally and vertically. The shales are either calcareous or noncalcareous but rarely contain arenaceous beds. They range from very plastic to hard, brittle, and closely laminated and possess all colors common to shale. The limestones are of all types except dolomitic, range from dense to coarsely crystalline or oölitic, and from purely calcareous to argillaceous or arenaceous, are commonly cherty only locally, are all shades of gray with reddish and greenish tints and some are stained brown, and may be massive or thin-bedded and shaly, evenly or irregularly bedded, cross-bedded, brecciated, or conglomeratic with rounded or angular pebbles of limestone and chert. Diverse types of shale and limestone are commonly present everywhere in each of these formations, and few of the char-

acters by which two formations may be differentiated at one place will serve the same purpose a few miles away. In areas where no faults exist, the various Chester formations may be traced laterally for considerable distances, but in faulted areas paleontology supplemented by local lithology and thickness is the only certain means of identification.

The large amount of shale in the Chester series favors slumping so that few outcrops exhibit more than a dozen feet of consecutive beds and formational contacts are rarely exposed. In most cases an exposure of a Chester section consists of outcrops of the more resistant sandstone and limestone layers separated by covered intervals representing the more shaly beds. The formations consisting principally of shale are rarely well exposed and at many places are indicated on the hillsides only by a terrace separating two sandstone formations. Because the sandstones are more resistant to weathering and erosion than are the limestone-shale formations they are not only more commonly exposed but beyond the glacial boundary they also control the topography and give rise to a series of cuesta-like ridges whose gentle back-slopes are the dip-slopes of the sandstones and on whose steep front-slopes the underlying limestone-shale formations crop out in narrow bands.

NEW DESIGN GROUP

The lower Chester group for which the name New Design is proposed consists of the Aux Vases, Renault, Bethel (or Yankeetown), and Paint Creek formations whose complete section occurs in outcrop only in Monroe and Randolph counties, Illinois, and the adjacent part of Missouri. The group is named from New Design township in Monroe County, Illinois, where all four formations are well developed.[16]

Aux Vases sandstone.—The oldest formation of the Chester series is named from Aux Vases River in Ste. Genevieve County, Missouri, and is well exposed in the adjacent Mississippi River bluffs. It is present in outcrop only from southern St. Clair County, Illinois, to southeastern Perry County, Missouri; it is the basal member of the Chester series except locally in the southern half of Monroe County where it is overlapped by the Renault formation. It varies greatly in thickness because it was deposited on an uneven surface of the Ste.

[16] Cumings (16, p. 514 footnote) has suggested but not formally proposed the Indiana names West Baden and Stephensport for the lower and middle Chester groups. The writers, however, consider it advisable to select names from other areas where the Chester stratigraphy has been studied in greater detail than it has in Indiana.

Genevieve and St. Louis limestones and also because it suffered erosion before the deposition of the Renault formation.[17]

In Illinois the Aux Vases sandstone is brownish fine-grained massive cross-bedded sandstone. In Missouri more or less variegated shaly beds occur in both the upper and lower parts of the formation and the middle massive sandstone is more yellowish than in Illinois. In Perry County, Missouri, the Aux Vases is coarser-grained and resembles the St. Peter formation locally, but the sand grains are commonly neither well rounded nor frosted. A basal conglomerate is present at many places in both Illinois and Missouri.

Renault formation.—The Renault formation is named from Renault Township, Monroe County, Illinois, in the eastern part of which it is well exposed along the two forks of Horse Creek. In Monroe and Randolph counties, Illinois, this formation includes sandstones, variegated arenaceous and calcareous shales, and limestones. Most of the limestone layers are greenish, dense, and arenaceous, but others are bluish gray, crystalline and pure, or argillaceous and shaly, and rarely oölitic. At many places the sandstones are flaggy and pierced by worm borings, and in the upper part of the formation are massive beds of sandstone which closely resemble the Aux Vases except that they contain numerous casts of *Lepidodendron* that are unknown in the lower formation.

The Renault is much the same in Ste. Genevieve County, Missouri, but on the south limestone beds become more conspicuous and the sandstones are absent. In the upper part of the formation one limestone which is 12 feet thick near the mouth of Saline Creek increases to 50 feet near St. Mary. Locally in the southern half of Monroe County, Illinois, the Renault overlaps the Aux Vases sandstone and becomes the basal member of the Chester series. A basal conglomerate containing pebbles of limestone and chert, and fragments of igneous rock at one place in Ste. Genevieve County, occurs at many localities in Missouri and in Monroe County, Illinois.

In southeastern Perry County, Missouri, and western Union County, Illinois, the Renault and Paint Creek formations have not been differentiated. In eastern Union County the Renault is composed mainly of limestone but contains some shale. The limestone is commonly light gray and dense but some beds are dark; some are more crystalline and crinoidal, and some are oölitic. The shale is mostly gray or greenish gray and more or less calcareous but some of it is

[17] Recent observations suggest that the basis for separating the Aux Vases and Renault formations is not so convincing as has previously been supposed and that the Aux Vases may be sandstone filling pre-Chester channels and therefore might be considered simply the local basal member of the Renault formation.

dark red. A nodular limestone interpreted as a basal conglomerate has been observed at one place.

In Johnson, Pope, and Hardin counties, Illinois, and adjacent parts of Kentucky, the Renault formation is divisible into two members which are locally unconformable. The lower or Shetlerville member is typically developed in Hardin County, Illinois, where it is about 30 feet thick but it thins and becomes indistinguishable both to the west and to the southeast. It consists mainly of calcareous shale with interbedded dark gray crystalline cross-bedded limestone. The upper member is composed of gray to bluish gray dense or crystalline limestone, some of which is oölitic and cross-bedded and more or less cherty in the upper part. The limestone beds are separated by partings or thin beds of calcareous shale. Farther east in Kentucky the shaly layers of the Renault formation become less conspicuous and it consists of a limestone that can not be distinguished from the Paint Creek formation where the Bethel sandstone is absent.

In Meade and Breckenridge counties and adjacent areas in Kentucky the Renault consists predominantly of limestone much of which is oölitic. Locally a bed of dark gray siliceous oölite containing fine quartz grains occurs in the lower part of the formation. This is underlain by a 2-foot layer of limestone conglomerate which rests directly on the Ste. Genevieve limestone. Some shale beds are present in the Renault in this area and the sandstone which is so conspicuous in the middle part of the formation farther north in Indiana is represented by a thin sandstone locally occurring at the base of the formation and elsewhere up to 28 feet above the base. This sandstone is not known south of Spurriers Mills and thickens gradually to the north. Locally it is developed in channels to a thickness of as much as 75 feet. At several places a thin seam of coal with underclay is associated with this sandstone.

The Renault formation in Indiana consists of three members named in ascending order Paoli, Mooretown, and Beaver Bend.[18] The upper and lower members consist of massive oölitic limestone, the lower of which constitutes the upper part of the Mitchell limestone. These are separated by the well defined Mooretown shale and sandstone member which contains very massive beds locally, as near New Amsterdam where it forms a conspicuous ridge overlooking Ohio River, and locally carries a thin seam of coal near Bloomington. It is possible that the horizon of this sandstone is represented in Hardin County, Illinois, by the unconformity that has been observed locally

[18] These and the following correlations of the Chester formations of Indiana, except where noted to the contrary, are suggested by Malott.

above the Shetlerville member, and that the Shetlerville and Paoli members are equivalent.

Yankeetown chert.—Although the Yankeetown chert, named from Yankeetown school in Monroe County, Illinois, is only 5–20 feet thick, it is a remarkably persistent formation in Monroe and Randolph counties, Illinois, and Ste. Genevieve County, Missouri. In outcrops it is composed of chert, arenaceous chert, quartzite, and hard siliceous limestone with a few thin local beds of shale. The chert and quartzite are commonly rose-colored and the chert is generally irregularly banded. The cherty character of this formation is probably largely surficial and related to weathering, because wells which pass through it encounter only sandstone at the Yankeetown horizon. The Yankeetown chert is believed to be unconformable on the Renault formation because it rests on various upper Renault beds and because the thickness of the Renault formation is so variable.[19]

Bethel sandstone.—In southern Illinois and western Kentucky the Yankeetown chert is represented by the Bethel sandstone, named from Bethel school, 3½ miles west of Marion, Crittenden County, Kentucky. Unfortunately the sandstone that is conspicuously exposed at this locality and that, therefore, might on casual examination be thought to be the Bethel is the lower part of the Cypress, talus from which almost completely covers the underlying Paint Creek and true Bethel formations.

The Bethel sandstone is a brownish moderately fine-grained sandstone, in part massive and cross-bedded and in part more thinly and evenly bedded. It is as coarse or coarser than the other Chester sandstones, at a few places it contains small quartz pebbles, and locally it is conglomeratic at the base. It lies unconformably on the Renault formation.

In Union County, Illinois, the Bethel sandstone is nowhere more than 10 feet thick. In the western part of the county and in southeastern Perry County, Missouri, it can not be recognized with sufficient certainty to separate the Renault and Paint Creek formations. In southern Johnson County, Illinois, it reaches a maximum thickness of 12 feet but is apparently absent at some places. To the east it thickens to 50 feet in the Ohio River bluff below Golconda, and on both sides of the river near Shetlerville it is at least 100 feet thick. Southeastward in Kentucky it thins. In the vicinity of Marion and Princeton it is represented by 25 to 40 feet of strata but has not been

[19] Recent observations suggest that the Yankeetown chert is in part the upper weathered portion of the Renault formation that extends downward to different horizons at different places.

recognized beyond Taylor's Chapel, about 2½ miles west of Elkton, Todd County.

On the east side of the coal field in western Kentucky the Bethel sandstone is again present and has been called the Sample sandstone from Sample in Breckenridge County. It is a variably developed flaggy to shaly sandstone uniformly present in Meade, Breckenridge, and Ohio counties and extends into Hardin and Grayson counties, although the formation thins and is absent a short distance south of Millerstown.

The Bethel sandstone occurs persistently in Indiana, where it has also been called Sample. It is represented locally by massive beds but in certain areas it is shaly.

Paint Creek formation.—The Paint Creek formation is named from Paint Creek in Randolph County, Illinois. In Monroe and Randolph counties, Illinois, and northern Perry County, Missouri, it uniformly consists of calcareous shale and interbedded limestone with a conspicuous dark red non-laminated clay 12 to 15 feet thick about 10 feet above the base. In the lower part of the formation shale predominates and the limestone beds are argillaceous and separated by numerous bluish shaly partings, but higher in the formation the limestone layers are more massive, purer, and crystalline, and at the top is a limestone bed about 10 feet thick.

In southeastern Perry County, Missouri, and western Union County, Illinois, the Renault and Paint Creek formations have not been separated. Although their total thickness is nowhere more than 80 feet and locally as little as 30 feet, the faunas indicate that both formations are present. They consist of shale, portions of which are variegated purple, yellow, and red, and of limestone, some of which is quite sandy.

Where the Bethel sandstone is recognized, so that the Renault and Paint Creek formations can be separated, the Paint Creek formation consists mainly of soft dark noncalcareous shale. Purplish sandy limestone, limestone conglomerate containing pebbles up to two inches in diameter, and lenses of irregularly bedded ripple-marked fine-grained calcareous sandstone containing shale pebbles occur at several horizons in the formation.

In southern Johnson County, Illinois, the lower portion of the Paint Creek formation is composed mainly of shale which grades upward into alternating limestone and shale. In western Hardin County, Illinois, it consists largely of dark laminated shale with local thin beds of sandstone or siliceous limestone, and where present in the eastern part of the county, it is mainly thin-bedded sandstone.

In Livingston and Crittenden counties, Kentucky, the Paint Creek formation is much the same as in Pope and Hardin counties, Illinois. To the southeast this formation becomes thicker and contains more limestone. In Caldwell County both the upper and lower parts consist of massive crystalline locally oölitic limestone beds separated by shaly partings, whereas the middle part of the formation is shaly. At some places a thin sandstone is present near the top of the Paint Creek formation. At the Caldwell-Christian county line this formation is almost entirely limestone.

Farther east along the southern border of the western Kentucky coal field the Bethel sandstone is absent and the Renault and Paint Creek formations can not be readily separated. In Meade, Breckenridge, Ohio, and parts of Hardin and Grayson counties, Kentucky, the Bethel sandstone is again present in the section and the Paint Creek formation consists of five rather variable members. Three of these, the lowermost, middle, and uppermost members, are composed largely of shale and the two intermediate members are somewhat massive limestones. Clastic beds reappear more abundantly in the Paint Creek formation to the north. In Indiana the formation contains three named members: the Reelsville limestone at the base, the Elwren sandstone and shale in the middle, and the Beech Creek limestone above. Both of the limestone members are more or less oölitic. The Elwren member commonly consists of two layers of sandstone separated by shale and has been traced as far south as Girkin in Warren County, Kentucky.

Girkin limestone.—From Todd County to Grayson County, Kentucky, the Bethel sandstone is absent and the Renault and Paint Creek formations together form a limestone unit that can not be easily subdivided. The name Gasper has been used for this limestone, but persistent miscorrelation has resulted in such confusion that the name is no longer useful. Consequently, these beds are now known as the Girkin limestone, named from a village in Warren County, Kentucky (61, p. 441).

The Girkin formation consists almost entirely of massive light gray limestone which can not be distinguished from the underlying Ste. Genevieve except by its fossil content. Some parts of the formation are highly oölitic and conspicuously cross-bedded, and such layers are extensively quarried for building stone near Bowling Green. The Girkin limestone is very susceptible to solution by ground water and has given rise to large areas of karst topography. The upper levels of Mammoth Cave are developed in it. Locally, gray shale as much as 20 feet thick is present at the top of the formation.

NEW DESIGN PALEONTOLOGY

Marine fossils in the New Design group are confined to the Renault and Paint Creek formations whose faunas are very closely related. They are characterized by the crinoid *Talarocrinus* and the bryozoan *Cystodictya labiosa,* which are restricted to these beds except that *Talarocrinus* (?) *simplex,* a form distinct from the Chester species, occurs in the Warsaw and Salem formations. *C. labiosa* is more common in the Paint Creek formation than in the Renault but specimens of *Talarocrinus* are generally more abundant in the Renault than in the Paint Creek.

The Shetlerville member of the Renault formation in southeastern Illinois and western Kentucky is abundantly fossiliferous and three species—*Spiriferina subspinosa, Talarocrinus buttsi,* and *Globocrinus unionensis*—are restricted to it. The coral *Amplexus geniculatus* is also very characteristic of this member and has not been certainly recognized elsewhere, although the same or a closely related form occurs rarely as high as the Glen Dean limestone. Of these four species only *T. buttsi* has been collected from the Renault formation farther east, where the basal part of the formation is largely limestone.

Pentremites with the "pyriformis" type of elongated bases occurs first in the Renault formation, and at many places the bases of *Lyropora* are abundant. Although *Archimedes* is conspicuous in most of the higher faunas it is rare in the Renault formation and only one species, *A. invaginatus,* is locally common.

In the Paint Creek formation *Pentremites* occur in great numbers and variety, and forms with concave ambulacral areas become common for the first time. *Archimedes* also becomes abundant and *A. compactus* is particularly characteristic of this formation, although it recurs rarely at higher horizons. *Glyptopora punctipora,* which also occurs in the Renault formation, is common at many places but is rarely found higher. *Pterotocrinus* first appears in the Paint Creek formation. *Chonetes chesterensis,* which is very unusual in other Chester formations, is locally common. *Spiriferina spinosa* is much more abundant than *S. transversa* in the Paint Creek fauna. *Camarotoechia purduei* is rare and is known only in the Paint Creek formation in the Eastern Interior basin.

HOMBERG GROUP

Although the original subdivision of the Chester series was made in southwestern Illinois, later studies showed that the lithology of the middle Chester group changed notably to the southeast, and because the formations recognized in Hardin County and the adjacent parts

of Illinois and Kentucky are more uniformly and widely developed, their succession in this area has been adopted as standard. It is possible that restudy may reveal the applicability of the standard classification to the southwestern Illinois section, but at present it is necessary to describe the formations in each area separately.

The name Homberg is proposed for the middle Chester group and is derived from the village of Homberg in Pope County, Illinois, near which it is well and typically developed. It includes the Cypress sandstone, the Golconda limestone, the Hardinsburg sandstone, and the Glen Dean limestone of the standard succession.

Cypress sandstone.—The Cypress sandstone, named many years ago from exposures on Cypress Creek in Johnson County, Illinois, is the most persistently thick and massive sandstone of the Chester series along the southern and eastern margins of the Eastern Interior basin. It thins notably westward, however, in northern Union and southern Jackson counties, Illinois, and is absent in Perry County, Missouri. In Randolph County, Illinois, the Cypress sandstone is represented in the Ruma formation.

The Cypress is generally a massive cross-bedded cliff-forming sandstone that weathers brown; it overlies the Paint Creek formation unconformably. Along the southern margin of the basin the lower part of the formation is more massive and is succeeded by thinner-bedded sandstone and shale that grade into the overlying Golconda formation. In Crittenden and Livingston counties, Kentucky, the middle part of the Cypress formation includes carbonaceous shales and a discontinuous coal bed which reaches a thickness of 4 feet at one or two places and was formerly mined. Another thinner but more persistent coal bed is present between the Cypress and Golconda formations in Edmonson, Grayson, and possibly also in neighboring counties, Kentucky.

In Christian and Caldwell counties, Kentucky, the Cypress consists chiefly of thin-bedded sandstone and shale but farther east in Warren County it is the most massive and thickest sandstone in the Chester series in that area. To the north along the eastern border of the basin in Kentucky the Cypress includes much shale and locally consists almost entirely of shale. In southwestern Indiana it is commonly a massive sandstone but locally it is composed almost wholly of shale.

Golconda limestone.—The Golconda limestone, named from the city of Golconda in Pope County, Illinois, succeeds the Cypress sandstone conformably. It constitutes the lower part of the Okaw formation in southwestern Illinois and is the highest Mississippian

formation in northern Perry County, Missouri, where it is represented by gray crystalline limestone which overlaps the Ruma and rests unconformably on the Paint Creek formation. Conglomerate composed of small angular limestone and chert pebbles occurs locally in the lower part.

In southeastern Perry County, Missouri, and in Jackson County, Illinois, the Golconda formation consists of massive crystalline limestone interbedded with shale. Some of the limestone is sandy and cross-bedded.

In eastern Union County, Illinois, the formation consists of an upper and a lower limestone separated by shale. The limestones are gray and granular with partings and beds of shale and with some oölite locally. The shale of the middle member is both argillaceous and calcareous and contains thin lenticular limestone layers. The three-part division of the Golconda continues some distance to the east but the shale content of the entire formation is variable, ranging from 50 to 90 per cent.

The Golconda formation attains its maximum development in Livingston County, Kentucky, where it consists of a variable succession of shales and limestones, the latter occurring more commonly in the upper part of the formation.

In Warren, Edmonson, and Grayson counties, Kentucky, the Golconda formation is mainly heavy-bedded gray limestone with some gray shale at the base and locally also at the top. Northward along the eastern border of the Eastern Interior basin it consists of a lower locally variegated shale 15–30 feet thick and an upper limestone about 30 feet thick. In Indiana the lower shale has been named Indian Springs[20] and consists of blue-gray to olive-green argillaceous beds. The overlying limestone to which the name Golconda has been restricted in Indiana is coarse, semi-crystalline, and locally oölitic. Chert, which is practically absent from all of the other Chester formations in Indiana, is abundant in this formation at many places as far south as Breckenridge County, Kentucky.

Hardinsburg sandstone.—Excepting the Cypress, the Hardinsburg is the most persistently thick and massive sandstone of the Chester series. It is named from Hardinsburg in Breckenridge County, Kentucky, and attains its maximum development near Marion in Crittenden County, Kentucky. Like the Cypress, it thins westward in northern Union and southern Jackson counties, Illinois, and is absent

[20] Malott correlates this shale with the upper part of the typical Cypress sandstone, but its character and the relative thickness of the underlying sandstone and overlying limestone indicate that it is probably the lower part of the Golconda formation.

from the Chester section in southeastern Perry County, Missouri. It is probably represented in Randolph County, Illinois, by the chert horizon in the middle of the Okaw formation.

The Hardinsburg sandstone overlies the Golconda formation unconformably. Considerable shale is present in the Hardinsburg and the proportions of shale and sandstone vary greatly from place to place. Although locally it forms conspicuous cliffs, its massive beds are generally friable and its thinner beds are shaly. In Livingston County, Kentucky, a coal bed is locally present in a shale zone in the middle of the formation. The Hardinsburg grades conformably through shales into the overlying Glen Dean limestone.

Glen Dean limestone.—The uppermost formation of the Homberg group is named from the village of Glen Dean in Breckenridge County, Kentucky.

As indicated by fossils, the Glen Dean limestone is represented in the Okaw formation of Randolph County, Illinois, and in the Chester sections of southwestern Jackson County, Illinois, and southeastern Perry County, Missouri, but it can not be satisfactorily separated from the underlying Golconda formation because the Hardinsburg sandstone is absent.

The Glen Dean formation consists of gray to buff, coarsely to finely crystalline, more or less sandy and irregularly bedded limestone and intercalated shale, some of which is locally highly colored. Shale is most abundant in the upper part of the formation and is mainly calcareous, although arenaceous beds are locally present. Conglomerate containing subangular chert pebbles has been observed, and one or more local disconformitites may occur within the formation.

In Union County, Illinois, the lower portion of the Glen Dean formation is mainly shale with some interbedded limestone and the upper part is mainly limestone with some interbedded shale. Most of the limestone is gray, moderately coarsely crystalline, massive, and crinoidal, but some of the more ferruginous layers weather buff. Dense beds are locally present, and a prominent oölite layer occurs near the top of the formation.

In Pope and Hardin counties, Illinois, and Livingston and Crittenden counties, Kentucky, shale generally predominates in the lower and limestone in the upper part of the Glen Dean, but the formation is quite variable and this situation is locally reversed. The limestones are generally gray, crystalline, and more massive than those of the Golconda, but there are some dense beds, some highly siliceous limestones are locally present near the base, some nearly black limestones have been noted, particularly in Hardin County, and at a number of places an oölite bed occurs near the top. The Glen Dean formation

contains some chert, although not nearly as much as do some of the higher Chester limestones. Sinkholes are locally developed in this formation. In Caldwell and Christian counties, Kentucky, the Glen Dean is largely shale with some interbedded limestone, especially in the upper part of the formation. At some places a hard dense limestone as much as 10 feet thick forms the base of the formation, and a sandstone as much as 9 feet thick is locally present in its midst.

Farther east along the southern border of the Eastern Interior basin the Glen Dean formation contains more limestone, and in Warren and Edmonson counties, Kentucky, it is mainly massive thick-bedded limestone, very similar to the Golconda, with a thin basal shale member. In Breckenridge County, Kentucky, and adjacent areas it possesses a lower and an upper shale member and a central limestone member which is divided into two parts by a shale zone near the middle. The limestone is generally conspicuously light-colored, crystalline, and crinoidal and contains some beds of oölite. The shales are commonly bluish but locally may contain greenish and reddish layers in both the lower and upper members. In Indiana the Glen Dean limestone is thick-bedded, massive, and more oölitic than any other Chester formation in that state.

Ruma formation.—In Monroe and Randolph counties, Illinois, the Paint Creek formation is succeeded with apparent conformity by the Ruma formation, named from a village in northern Randolph County near which it is well exposed in the tributaries of Horse Creek. The Ruma formation is locally 75 feet thick in Illinois but is entirely absent west of Mississippi River. It consists principally of shale with considerable interbedded sandstone, and a thin limestone member is locally present. The middle part of the formation is the most arenaceous and contains thin-bedded sandstone and sandy shale, but at some places similar beds are present in the upper part of the formation. Some of the sandstone is ripple-marked, and casts of *Lepidodendron* are abundant at a few places. The shaly strata are characteristically variegated and contain reddish and purplish beds similar to some of the Renault shales in this same region. Conspicuously variegated shales occur in no higher Mississippian formation in southern Illinois except the Kinkaid, in which they are only locally developed.

The Ruma formation is approximately equivalent to the Cypress sandstone of southeastern Illinois and western Kentucky.

Okaw limestone.—The Okaw formation was named from Okaw (Kaskaskia) River in Randolph County, Illinois. As originally defined it included all strata between the Ruma formation and the Menard limestone in Randolph County, Illinois. For many years the formation has been informally subdivided into upper and lower Okaw

beds that were commonly correlated with the Glen Dean and Golconda formations of the Ohio Valley. It has recently been determined, however, that the upper Okaw consists of strata equivalent to the Tar Springs sandstone, Vienna limestone, and Waltersburg sandstone of the standard section (59). Because the formation as originally defined transgresses the boundary between middle and upper Chester groups, and because the old upper Okaw is a mappable unit, it is now proposed that the name Okaw be restricted to the old lower Okaw beds and the name Baldwin formation be used for the beds of upper Chester age formerly classed as upper Okaw.

The Okaw formation as thus restricted consists of about 200 feet of limestones alternating with shales, both types of strata being variable. The limestones are commonly light gray in color and many strata are more or less crystalline. A cherty zone 10 feet or less thick occurs in the middle of the formation and is believed to mark the horizon of the Hardinsburg sandstone just as, in this same region, the Bethel sandstone is represented by the Yankeetown chert. This chert horizon has not been recognized throughout the extent of the Okaw formation and may not be persistent, so that Golconda and Glen Dean beds can not be consistently separated. Chert elsewhere in the formation is practically absent. Many of the limestones in the lower half of the Okaw are more or less oölitic and one conspicuous oölite, the Marigold member, which is well exposed near the village of that name, occurs about 75 feet above the base. Above the chert horizon oölites are generally absent but here, particularly at the very top of the formation, occur the most massive limestone beds.

HOMBERG PALEONTOLOGY

One of the most important fossils which first appears in the Homberg or middle Chester group is *Camarophoria explanata*. This little brachiopod has been collected from the Cypress sandstone both in southern Illinois and western Kentucky, is present almost everywhere in the Golconda limestone, and persists in all of the higher Chester limestones. The most important fossil that is restricted to the Golconda formation is *Pterotocrinus capitalis*, whose wing plates characterize the lower part of the formation from Johnson County, Illinois, to Christian County, Kentucky. Associated with this species is the rarer but equally distinctive *Pentremites obesus*, which is the largest known species of the genus. Other fossils which so far as known are confined to the Golconda include *Rhynchopora perryensis*, *Archimedes lativolvis*, and a largely undescribed assemblage of Salem-like molluscan species.

The fauna of the Glen Dean formation is rich in bryozoans at many localities. The two most important species are *Prismopora serratula* and *Archimedes laxus*. In the southeastern tip of the Eastern Interior basin these forms are also abundant in the Golconda formation but are unknown in that formation farther west in Kentucky or in southern Illinois. *Prismopora* recurs less commonly in the Vienna and more rarely in the Menard faunas. Four other species which are believed to be almost exclusively confined to the Glen Dean are *Pentremites spicatus*, *Pterotocrinus bifurcatus*, *P. acutus*, and *Cheilotrypa hispida*. *P. spicatus*, however, occurs in southwestern Illinois in beds of Vienna age in the Baldwin formation.

ELVIRA GROUP

The name Elvira, derived from a township in Johnson County, Illinois, where all of the formations of the standard section are well developed, is proposed for the upper Chester group. This group consists of eight alternating sandstone and limestone-shale formations, namely, the Tar Springs sandstone, the Vienna limestone, the Waltersburg sandstone, the Menard limestone, the Palestine sandstone, the Clore limestone-shale, the Degonia sandstone, and the Kinkaid limestone. The sandstones, which are similar to those in the New Design and Homberg groups, are best developed in southern Illinois and the adjacent part of western Kentucky. Toward the southeast they become thin and shaly and can not be recognized in the extreme southeastern part of the Eastern Interior basin. In comparison with the limestones of the New Design and Homberg groups, the limestones of the Elvira group are generally finer-grained and darker-colored, have fewer light gray crystalline beds, are somewhat siliceous, contain abundant chert at some horizons, commonly weather to smooth hard surfaces without crumbling, and generally possess uneven hummocky bedding planes. The limestone strata of the Elvira group thin and become shaly to the southeast and in the southeastern part of the basin the entire Elvira group consists mainly of shale which has not yet been subdivided into the standard formations.

Tar Springs sandstone.—The Tar Springs formation, which receives its name from a locality 3 miles south of Cloverport in Breckenridge County, Kentucky, is one of the thicker and more persistent sandstones of the Chester series. It is probably represented by the arenaceous beds in the lower part of the Baldwin formation in Monroe and Randolph counties, Illinois. From southeastern Perry County, Missouri, to Warren County, Kentucky, the Tar Springs sandstone generally consists of lower and upper massive parts separated by a

shaly zone that is commonly carbonaceous and locally contains a thin bed of coal. In Caldwell and Christian counties, Kentucky, it has the greatest development of any Chester sandstone in the Eastern Interior basin. East from Warren County, Kentucky, and north along the eastern border of the basin the Tar Springs sandstone is erratically developed and may consist of either massive or shaly beds or may be locally absent.

Vienna limestone.—The Vienna formation, which is named from Vienna in Johnson County, Illinois, is one of the thinner limestone-shale formations of the Chester series. It is probably represented in Randolph County, Illinois, by the shale and limestone beds in the middle of the Baldwin formation. It is the youngest Chester formation in Missouri, where it is represented by thick residual chert on a few hill tops in southeastern Perry County. The Vienna formation persists across southern Illinois and as far as eastern Christian County, Kentucky, although it has not been distinguished from the Menard formation in Hardin County, Illinois.

The Vienna formation is somewhat variable, but the lower part is dominantly limestone and the upper part dominantly shale. The limestone is mainly fine-grained and bluish gray to nearly black, in beds one foot or less thick, some of which weather to light brown, spongy masses. Much dark-colored chert occurs in layers 1 to 3 inches thick. The shales are bluish gray to black except locally in southern Crittenden County, Kentucky, where some reddish layers are present A few inches of coal occur in Pope County, Illinois, about 4 feet below the limestone. In northeastern Christian County, Kentucky, there are no limestone beds in the Vienna formation and it has not been differentiated farther east.

In Breckenridge and Ohio counties, Kentucky, the Tar Springs sandstone is overlain by a persistent limestone layer, rarely more than 10 feet thick, which is cherty and contains a fauna similar to that of the Menard formation farther west. If this bed is equivalent to the basal Menard, both the Vienna and Waltersburg formations are absent in this region. The shaly beds that intervene between the Tar Springs and Wickcliff sandstones in southwestern Indiana may be the equivalent of either the Vienna formation or the middle shaly portion of the Tar Springs sandstone as recognized in southern Illinois and western Kentucky. If the latter correlation be correct, the Wickcliff sandstone is the upper massive portion of the Tar Springs formation of that region.[21]

[21] Malott correlates the shale interval and the Wickcliff sandstone with the Vienna and Waltersburg formations, respectively, but Sutton has not certainly recognized either of the latter formations in Breckenridge and Ohio counties, Kentucky.

Waltersburg sandstone.—This formation, which is named from Waltersburg in Pope County, Illinois, is the thinnest, most shaly, and, excepting the Aux Vases, the most restricted sandstone of the Chester series. It is massive only in the vicinity of its type locality and also locally east of Marion in Crittenden County, Kentucky, at which places it resembles the Cypress sandstone. Elsewhere it consists of dark shale with thin interbedded sandstone strata which are generally dark-colored and carbonaceous where fresh and are characteristically cut by two sets of joints into long narrow pieces resembling stovewood. The sandy layers thin to the east and are absent in northwestern Christian County, Kentucky, beyond which the Waltersburg formation has not been recognized. This formation is probably locally represented in Randolph County, Illinois, by discontinuous sandstone at the top of the Baldwin formation.

The resistant Wickcliff sandstone of southwestern Indiana, which is persistent from Perry County to Patoka River, has been correlated with the Waltersburg formation by Malott, but more probably it is equivalent to the upper massive beds of the Tar Springs sandstone.

A thin coal is persistent between the Waltersburg and Menard formations in Johnson, Pope, and Hardin counties, Illinois.

Baldwin formation.—The name Baldwin formation is introduced for strata of upper Chester age in Randolph County, Illinois, that were formerly included in the Okaw formation and have been previously termed upper Okaw or Plum Creek beds of the Okaw formation. The name is derived from a town east of Kaskaskia River, south of which these strata are well exposed. On the accompanying areal map (Fig. 4) this formation has not been differentiated from the Okaw limestone and is included with the middle Chester group.

The Baldwin formation is generally from 60 to 75 feet thick and consists principally of shaly strata. Arenaceous beds, locally grading into sandstone, occur at bottom and top and represent the Tar Springs and Waltersburg sandstones of the standard Chester section. The Tar Springs member is best developed in the vicinity of Chester where it appears to succeed the Okaw limestone unconformably. The Waltersburg member achieves its greatest development farther north where it locally exhibits the jointing so characteristic of this sandstone elsewhere. Dark gray fine-grained limestone with more or less black chert occurs in one or more layers in the middle part of the formation and represents the Vienna limestone of the Ohio Valley. Although all three of these formations are undoubtedly present in the Baldwin, their development is not consistent and they can not be satisfactorily separated.

Menard limestone.—The Menard formation, which is named from Menard in Randolph County, Illinois, is one of the most uniform formations of the Chester series. It consists mainly of limestone with minor amounts of interbedded shale, although shaly zones occur locally at the base, in the middle, and at the top of the formation. It is not as cherty as the Vienna formation. In Christian County, Kentucky, the Menard formation can not be distinguished in the limestone-shale sequence between the Tar Springs and Palestine sandstones because the Waltersburg sandstone is absent.[22] Farther east the limestone in this interval is largely replaced by shale and the Menard formation has not been differentiated. It reappears in Ohio and Breckenridge counties, where it consists of two persistent dense slabby limestones separated by shale whose top is about 170 feet above the top of the Glen Dean and 95 feet below the bottom of the Kinkaid.

In southwestern Indiana the Menard formation may be represented by the Siberia limestone and the underlying and overlying shale intervals. The Siberia limestone is commonly a single ledge which is coarsely crystalline and cross-bedded and differs from most other thin limestones in the Elvira group of this region by being abundantly fossiliferous. Below the Siberia limestone and separated from it by a few feet of shale is a thin persistent layer of yellowish commonly fossiliferous limestone.

Palestine sandstone.—The Palestine formation, which is named from Palestine Township of Randolph County, Illinois, is the most persistently thin-bedded sandstone of the Chester series excepting the Waltersburg formation. It is generally thin-bedded and flaggy and contains much sandy shale. More massive beds occur locally, as near Glen Dale in Pope County, Illinois, and in northern Christian County, Kentucky. Within a short distance beyond the latter locality the formation becomes shaly and loses its identity in the Leitchfield shale. A thin coal locally occurs at the top of the Palestine sandstone in Jackson and Hardin counties, Illinois.

The Palestine sandstone also occurs in Breckenridge County, Kentucky, on the eastern border of the Eastern Interior basin, where it is locally nearly as thick and massive as the Tar Springs sandstone. In southwestern Indiana it is probably represented by the thin Bristow sandstone.

Clore formation.—Throughout its extent the Clore formation,

[22] A new name might be proposed for this limestone-shale interval, but it would be applicable in only a very small area and the writers prefer the hyphenated term Vienna-Menard because it indicates the exact stratigraphic equivalence of these beds to the formations of the standard section.

named from Clore School near Chester in Randolph County, Illinois, is mainly shale, and consequently good exposures are rare. Limestone beds, which are generally most abundant in the upper part but locally constitute nearly the whole formation, are fine-grained and dark-colored like the other limestones of the Elvira group.

The Clore has been recognized as a distinct formation as far east as central Christian County, Kentucky. Farther east the overlying Degonia sandstone is not distinguishable and the beds from the base of the Clore to the top of the Chester constitute one of the thickest limestone sections of the Chester series in the Eastern Interior basin. This consists of 250–300 feet of light to dark gray or locally bluish limestone with lenticular shale and sandstone strata and some chert.[23] East of Logan County, Kentucky, this part of the geologic column becomes predominantly shale and the Clore formation has not been differentiated from the remainder of the Elvira group. In Indiana the Clore is known as the Gennet Creek formation and consists of 10–35 feet of predominantly shaly beds.

Degonia sandstone.—The highest sandstone formation in the Chester series is named from Degonia Creek which separates Jackson and Randolph counties, Illinois. It is thickest at its type locality and thins progressively to the east. In Jackson and Union counties, Illinois, massive beds in the middle and upper parts of the formation produce cliffs and closely resemble the Pennsylvanian sandstones of this region, but in Johnson and Pope counties, Illinois, the Degonia consists of thinner and more shaly strata. In western Kentucky it is nowhere a prominent formation. In eastern Crittenden, northeastern Caldwell, and northern Christian counties the Degonia formation is a rather inconspicuous sandy horizon and farther east it completely loses its identity.

The Degonia formation occurs intermittently along the eastern side of the Eastern Interior basin in Kentucky as a thin sandstone with a maximum thickness of about 18 feet. In southwestern Indiana it is probably represented by the Mt. Pleasant sandstone, named from a town in Perry County. This sandstone is hard and even quartzitic in places but is locally interlaminated with shale and at some localities grades into sandy limestone breccia.

Kinkaid limestone.—The youngest formation of the Chester series is named from Kinkaid Creek in Jackson County, Illinois. It is one of

[23] A new name might be proposed for this limestone sequence but it would be applicable in only a very small area and the writers prefer the hyphenated term Clore-Kinkaid formation because it indicates the exact stratigraphic equivalence of these beds with the formations of the standard section.

the more uniformly developed formations and consists mainly of limestone with minor amounts of shale which increase to the east. The limestone, which is fine-grained and dark-colored, closely resembles similar beds in the Menard formation. Chert is locally abundant, particularly in the upper part, and a chert layer that may be 5 or more feet thick occurs in the lower part of the formation and persists across most of southern Illinois and into western Kentucky. Some of the Kinkaid chert is lighter colored than that of the Menard. Reddish and olive-green shales are present in the lower part of the Kinkaid formation in Johnson and Pope counties, Illinois, and Crittenden County, Kentucky, and local sandy layers appear in both the lower and upper parts, particularly in the east. Considerable shale is present locally in this formation in northern Christian County, Kentucky, but to the east as far as Logan County it is mainly limestone, and because the Degonia sandstone can not be identified in this region the Kinkaid and Clore formations have not been distinguished. Farther east the Kinkaid formation becomes very shaly and has not been differentiated.

In southwestern Indiana the Negli Creek limestone, which occurs at the top of the Chester section, and the underlying shale are probably the equivalent of the Kinkaid formation. The limestone, which is named from Negli Creek in Perry County, is massive and fossiliferous and continues as a recognizable unit into Hancock and Ohio counties, Kentucky.

Leitchfield formation.—The thick shale which constitutes the Elvira group in Logan and Butler counties, Kentucky, and farther east, is known as the Leitchfield formation, named from a town in Grayson County, Kentucky. Conspicuous reddish and greenish shales occur in the lower part of this formation from Butler to Breckenridge counties, and lenticular limestones of varied character occur principally at three horizons which are probably to be correlated with the Vienna, Menard, and Kinkaid formations. In northwestern Breckenridge County, Kentucky, the upper Chester sandstones occur and extend more or less persistently into southwestern Indiana where most of the limestone formations are recognizable although represented largely by shale.

The name Buffalo Wallow has been used for all of the Chester strata above the Tar Springs sandstone in the southeastern part of the Eastern Interior basin, but as all of the formations of the Elvira group with the possible exception of the Vienna and Waltersburg can be identified at the type locality of the Buffalo Wallow in Breckenridge County, Kentucky, the name has little value.

ELVIRA PALEONTOLOGY

The faunas of the Elvira group are neither so well known nor so characteristic as are those of the New Design and Homberg groups. The Elvira limestones are all more or less fossiliferous but they are generally so fine-grained, dense, and siliceous that fossils sufficiently perfect for identification can be collected only with difficulty and calcareous shales or shaly limestones that have yielded such prolific faunas at several lower horizons are neither abundant nor well exposed.

The best defined fauna of the Elvira group occurs in the Menard formation and is characterized by *Pentremites fohsi*, which is only slightly smaller than *P. obesus* of the Golconda, and *Pterotocrinus menardensis*. Both of these species are confined to the lower part of the formation *Composita subquadrata* and *Eumetria costata* are common, whereas the older species *C. trinuclea* and *E. vera* are rare or absent. The typical form of *Spirifer increbescens* is introduced. *Sulcatopinna missouriensis* first appears in the Vienna and continues into the Kinkaid but is most common and locally abundant in the Menard formation.

The Vienna fauna contains no peculiar species but may be recognized by the association of certain forms, such as *Prismopora serratula*, which is largely unknown in the higher formations, with others, such as *Sulcatopinna missouriensis*, which are almost entirely confined to the Elvira group.

The Clore fauna consists of either long-ranging Chester forms or those which occur throughout the Elvira group. The only species of particular significance is *Batostomella nitidula* which is sparingly present in the other Chester formations but is very common on the surfaces of some of the Clore limestone layers.

The Kinkaid fauna is less well known than that of any other Chester formation. Although it includes several typical Elvira species, none are known to be distinctive.

CHESTER SEDIMENTATION

The pre-Chester Mississippian formations of the upper Mississippi Valley are dominantly limestone with considerable shale and little sand. In the Chester epoch sands were widely deposited in the Eastern Interior basin and this change in sedimentation must have been occasioned by some notable change in the neighboring land areas.

Chester strata do not extend as far north as do the older Mississippian formations. It is not known how far the Chester seas extended beyond the present northern boundaries of the strata, but it is

believed that they were much more restricted than their predecessors. The northern borders of the Chester are covered by the Pennsylvanian system and therefore a direct comparison, which might throw much light upon the source of the sediments, can not be made between the developments of these formations in the northern and in southern parts of the Eastern Interior basin.

Lateral variation.—The clastic strata in the Chester series are generally thickest and coarsest in the region of southern Illinois and western Kentucky adjacent to the Ohio River. Lateral variation both to east and west is considerable and differs for each of the three Chester groups.

The Aux Vases sandstone is best developed along Mississippi River and thus differs from all other Chester sandstones except the Degonia, but unlike the Degonia it does not crop out farther east in southern Illinois and western Kentucky. The Bethel sandstone is represented near Mississippi River only by a thin cherty or arenaceous horizon and is locally absent but thickens greatly to the east and then again thins and disappears. Both the Renault and Paint Creek formations in the Mississippi River counties appear to be sublittoral deposits. They are progressively less clastic farther east and consist of a considerable thickness of very pure limestone in the southeastern part of the basin beyond the limits of the Aux Vases and Bethel sandstones.

Neither the Cypress nor the Hardinsburg sandstones are typically developed in the Mississippi River counties. The Cypress is approximately equivalent to the Ruma formation of the region but the Hardinsburg is represented only by a cherty zone in the Okaw formation, thus resembling the Bethel. The Cypress and Hardinsburg sandstones are extensively developed on the east, however, and persist to the southeastern extremity of the Eastern Interior basin far beyond the limits of all other arenaceous Chester formations.

The Golconda and Glen Dean formations consist principally of limestone and the associated shale is least abundant in the northern Mississippi River counties and in the southeastern tip of the basin, and most conspicuous in those adjacent to Ohio River.

The upper Chester formations are relatively more persistent and uniform in southern Illinois than are the lower formations, but in western Kentucky both the limestones and the sandstones grade into a single thick shale unit.

The Chester sandstones that thin and disappear along the southern margin of the Eastern Interior basin in western Kentucky reappear to the north on the eastern side of the basin near Ohio River

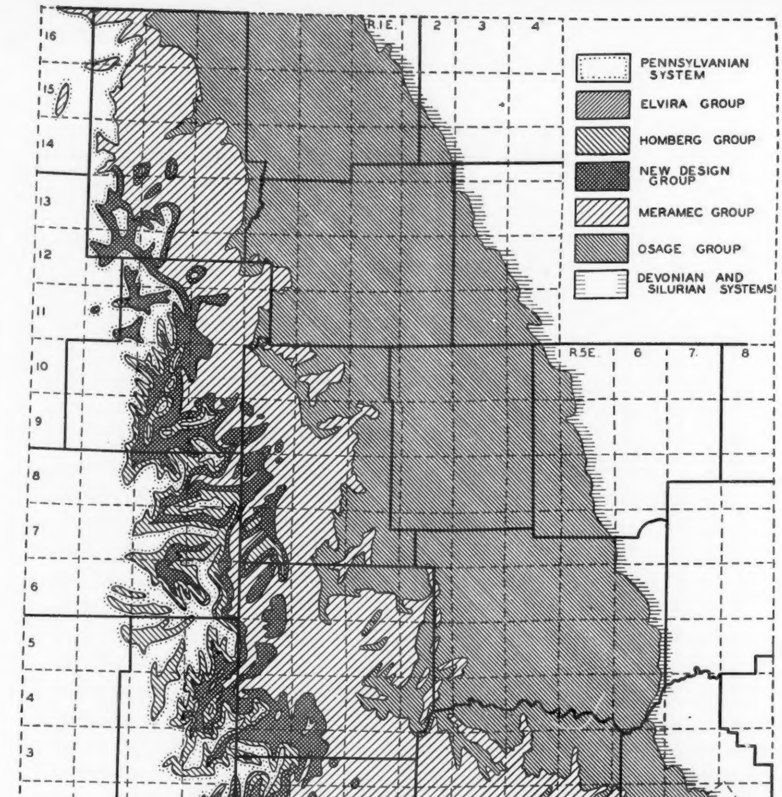


FIG. 10.—Map showing distribution of outcropping Mississippian rocks in Indiana. Areal geologic mapping under auspices of Indiana Department of Conservation, Division of Geology.

and extend northwestward into Indiana. They are not as thick in Indiana, however, as in southern Illinois and western Kentucky, and the alternating limestone-shale formations consist much more dominantly of shale than they do farther southwest.

Source of sediments.—The source of the clastic Chester sediments has not been satisfactorily determined and some of the evidence appears to be contradictory. The only conclusion that seems to be entirely justified is that the sediments which constitute the sandstone formations were not derived from the southeast because all but two of the sandstone formations are absent in the southeastern part of the Eastern Interior basin and these two are much thinner than they are farther west. On the other hand it seems likely that much of the shale in the Elvira group was contributed by a land mass on the southeast because the limestones of the group almost entirely give way to shale in this direction. If these conclusions are correct, changes in the condition of Appalachia must have occurred at the close of Homberg time, because as shown by the thick and pure limestones of the New Design and Homberg groups, no important amount of clastic sediment had been previously received by the basin from this source.

Ozarkia appears to have been land during the Chester epoch and it probably contributed sediment to the Eastern Interior basin, especially during New Design and early Homberg time. The Renault formation of Monroe County, Illinois, is distinctly sublittoral and the igneous pebbles which occur locally in its basal conglomerate may have been obtained from Ozarkia. Conspicuous redbeds occur at several different horizons in this part of the basin but are uncommon elsewhere. They are present in the Fern Glen formation and the Hoffner member of the Ste. Genevieve, and are more or less characteristic of the Renault, Paint Creek, Ruma, and Kinkaid formations. It is possible that these red sediments were derived from the residual clays formed by the weathering of the limestones and dolomites of the Ozark region. It seems impossible, however, that Ozarkia could have contributed the kind and quantity of sand that is present in the Chester sandstones. Also, all of these sandstones with the exception of the Aux Vases and Degonia are much thicker and coarser some distance east and it is evident, therefore, that another source for this material must be sought.

The introduction of arenaceous members in the New Design and Elvira groups and the reduction in thickness of the limestones in the New Design and Homberg groups northward into Indiana might be considered to indicate a northern source for the Chester sands. The various Chester formations, however, exhibit no progressive changes

along their strike from a short distance north of Ohio River to their northernmost outcrops, and except for local variations there is little change in the thicknesses of the formations or the materials of which they are composed. On the other hand, evidence of progressively off-shore conditions is given by the limestone-shale formations of the Indiana Chester as they are traced down the dip. At their most eastern outcrops from Putnam to Harrison counties these formations are represented largely by shale, and limestone layers are thin and discontinuous or entirely absent. To the west, however, the limestone layers become progressively thicker and more conspicuous to the points where they pass below drainage, and well records show still further thickening in that direction. Westward thickening of the Chester sandstones comparable to that of the limestones has not been recognized in southwestern Indiana.[24] Lateral variation, therefore, gives no indication that the sands of the Chester series were derived from the north.

Llanoria, from which much clastic material was contributed to a large basin of deposition in Arkansas and Oklahoma, is known to have been in existence as a land area in the Gulf Coastal region not only in late Mississippian but also in subsequent Pennsylvanian time. In Arkansas, the southern derivation of the Jackfork sediments, believed by some to be of upper Mississippian age, is plainly indicated by the increase in coarseness and amount of sand as the old land area is approached, and the northward direction of the currents from which the Wedington sandstone member of the Fayetteville (Chester) formation was deposited is clearly shown by the prevalent direction of cross-bedding (15, pp. 68, 115).

The Bethel, Cypress, and Hardinsburg (Hartsell as restricted by Butts) sandstones are present in the Chester section of northwestern Alabama but in the northeastern part of the state the Bethel and Cypress are absent and the Hardinsburg is much reduced in thickness (11, pp. 184, 189, 191, 192–94). It seems likely, therefore, that the Chester sands of this region were derived from Llanoria on the west.

Studies of the heavy-mineral content of several of the Chester sandstones of Indiana show close similarity of every sample, and other samples taken from the Mansfield sandstone (Pennsylvanian) of the same region contain an almost identical mineral suite. The mineralogical and physical characters of the sands point toward an original source in an area of igneous rocks and there is no evidence particularly suggesting an intermediate period of deposition. The most important characters of all these sands are: (1) a very high proportion

[24] C. A. Malott, personal communication.

of a mineral identified as leucoxene, which makes up 50–75 per cent of the heavy-mineral concentrate, and (2) a very small amount of garnet. This combination appears to exclude from consideration all known possible sources on the north and east, as highly titaniferous rocks are either absent or associated with others that are highly garnetiferous.

The evidence presented suggests that much of the clastic Chester sediment of the Eastern Interior basin may have been carried northward from Llanoria, especially as there is no evidence of any physical barrier having separated the sedimentary basin of northern Arkansas from that of southern Illinois and western Kentucky during late Paleozoic time, although it is not known that this area could have furnished sediments mineralogically similar to the Chester sands (36). Unfortunately neither the character and thickness of the Chester succession in northeastern Arkansas nor the faunas preserved in its several fossiliferous members are favorable to such a conclusion. The notable alternation of sandstone and limestone-shale units in the Chester series in southern Illinois and western Kentucky is lacking in the Chester of northern Arkansas, where its complete thickness near Batesville is less than half of that in the lower Ohio Valley. Moreover, the faunas of the Arkansas formations, although including several characteristic Chester species, possess a very different general aspect and apparently lack most of the useful guide fossils of the standard section, so that only general correlations are possible between these two regions.

It seems probable that a single land area furnished the greater part of the coarser clastic Chester sediments of the Eastern Interior basin, although some coarse and much fine material was undoubtedly brought into the basin from other directions. Because of the unsatisfactory and somewhat contradictory character of the evidence, the problem of the origin of the Chester sediments remains unsolved. Perhaps more careful studies in other regions or a more detailed knowledge of the subsurface stratigraphy of the Chester series in Illinois may furnish the solution to this problem.

Sedimentary environments.—The abundance of fossils in the limestones and calcareous shales of the Chester series attests the marine origin of these sediments and because of their intimate association there is little doubt that the non-calcareous shales were also deposited under marine conditions. The variability of these beds both laterally and vertically is proof that the Chester seas were shallow.

The Chester sandstones are similar in many respects to the overlying Pennsylvanian sandstones for which they have been mistaken

repeatedly. That they were deposited in shallow water is shown by the cross-bedding, by ripple-marked surfaces, by layers of clay-pebble conglomerate, and by locally abundant vegetable remains. The stems of *Lepidodendron* and other Carboniferous plants, which are generally preserved as casts, might have floated considerable distances from shore, but delicate and well-preserved leaves could not have been transported far. Thin coal beds are associated with the Chester sandstone formations at eight different horizons and several of these that are extensive over many square miles are almost certain evidence of terrestrial conditions. However, at a few localities, the occurrence of marine fossils preserved as casts shows that portions of some of these formations are marine. The marine fossiliferous zones generally occur in the lower and upper parts of the sandstone formations and suggest that after a period of limestone-shale deposition there remained local and shallow marine bays or estuaries which were filled with sand, and also that sand was deposited or reworked by the readvancing marine waters of the next limestone-shale period. The rare presence of marine fossiliferous zones in other parts of the sandstone formations, as in the middle of the Cypress sandstone of Christian County, Kentucky, proves that other parts of these formations also may be marine. It is probable, however, that considerable parts of the Chester sandstones are alluvial deposits laid down on a broad coastal plain.

Cycles of sedimentation.—A striking feature of the Chester series is the alternation of sandstone and limestone-shale formations. These formations may be paired to form units consisting of a lower sandstone formation probably largely continental in origin and an upper marine limestone-shale formation. Eight of these units occur in the Chester series in Illinois and ten in Indiana, and each represents a cycle of sedimentation. In four or five of the units thin coal beds are present between the sandstone and limestone-shale portions and thus these units closely resemble the cyclothems of the Pennsylvanian system.[25]

PRE-PENNSYLVANIAN UNCONFORMITY

A marked unconformity occurs at the base of the Pennsylvanian system in the central United States. In the southern, eastern and central parts of the Eastern Interior basin Pottsville beds rest on Chester formations, but in the northern and western parts of the basin the Pennsylvanian system overlaps successively older formations until in LaSalle County, Illinois, it lies on the lower part of the St. Peter sandstone (Ordovician), a horizon which occurs at least

[25] J. M. Weller, "Cyclical Sedimentation of the Pennsylvanian Period and Its Significance," *Jour. Geol.*, Vol. 38, (1930), p. 101.

5,000 feet below the base of the Pennsylvanian in the southern part of the state. It does not follow, however, that any such thickness of strata was removed from north-central Illinois by post-Mississippian, pre-Pennsylvanian erosion, because (1) most of the Paleozoic formations thin considerably to the north in this region, and (2) several important intervals of emergence and erosion occurred during the Paleozoic era, with resulting unconformities the records of which have been destroyed near LaSalle and in neighboring areas.

Along the southern margin of the basin from Union County, Illinois, to Christian County, Kentucky, Pennsylvanian beds generally rest on a variable thickness of the Kinkaid limestone, but locally, as near Alto Pass in Union County, Illinois, where the Pennsylvanian overlaps on formations as low as the Menard, and in eastern Caldwell and western Christian counties, Kentucky, on formations as low as the Palestine formation, pre-Pennsylvanian erosion has removed several of the higher Chester formations. It is uncertain whether the unconformities at these places represent channels cut in the Misssissippian surface or the truncation of pre-Pennsylvanian structures.

East of Christian County, Kentucky, the Pennsylvanian system generally overlies a variable thickness of the Leitchfield formation. In eastern Edmonson County the relief of the Mississippian surface exceeds 300 feet and a channel cut into and probably through the Cypress sandstone is filled with Pottsville sediments. A succession of coarse conglomeratic deposits which overlap formations as old as the St. Louis limestone along the Taylor-Marion county line marks the probable eastward extension of this channel.

A pre-Pennsylvanian channel in northeastern Martin County, Indiana, has been cut into Chester strata to a depth of at least 140 feet through beds ranging from the Glen Dean down to the Reelsville limestone. It extends in a north-northeast direction at least to about 2 miles west of Williams in Lawrence County and in the opposite direction to McBrides Bluff on White River and probably to Shoals. It is possible that other comparable channels occur in this region.

The northward overlap of Pennsylvanian beds is well shown along both the western and the eastern margins of the Eastern Interior basin. Along the western side the Kinkaid limestone is cut out near Marys River, the Degonia sandstone near Bremen, the Clore formation near Palestine, the Palestine sandstone at Ninemile Creek southeast of Evansville, the Menard limestone between Evansville and Baldwin, the Baldwin, Okaw and Ruma formations near Red Bud, all in Randolph County, Illinois, the Paint Creek and Yankeetown

formations east of Waterloo in Monroe County, and the Renault and Aux Vases formations near the county line north of Waterloo, where the Pennsylvanian system lies on the St. Louis limestone because the Ste. Genevieve limestone is locally absent. However, a short distance north the Ste. Genevieve, Aux Vases, Renault, and Yankeetown formations reappear from beneath the Pennsylvanian and crop out in a small area extending to the Mississippi River bluffs. An outlier of Pennsylvanian in the syncline west of the Waterloo anticline is underlain by Ste. Genevieve and lower Chester formations, and another in and about St. Louis overlies the St. Louis limestone. At numerous places east of the border of the main mass of the Pennsylvanian deposits there are inliers of lower and middle Chester formations which appear to mark buried pre-Pennsylvanian hills.

Near Alton in Madison County, Illinois, the Pennsylvanian system succeeds the Ste. Genevieve formation. North to Mercer County the Pennsylvanian border is very irregular and the strata of this system rest on successively older formations. The pre-Pennsylvanian surface is irregular, having a relief of probably more than 100 feet, and is pitted with sinkholes in certain areas. The details of the geology of this district, however, are greatly obscured by a thick covering of glacial drift.

Similar overlap of Pennsylvanian strata on successively older formations occurs northward along the eastern side of the Eastern Interior basin in Indiana. The Negli Creek limestone is cut out finally in central Perry County, the Mt. Pleasant sandstone near Branchville and Bristow in the same county, the Bristow sandstone near the northern border of the county, the Siberia limestone near Schnellville and Wickcliff in DuBois and Crawford counties, the Wickcliff sandstone near Patoka River, the Tar Springs sandstone near Dover Hill and Shoals in Martin County and French Lick in Orange County, the Glen Dean limestone near Owensburg and the Hardinsburg sandstone near Cincinnati in Green County, the Golconda limestone west of Bloomington, the Cypress and Beech Creek formations near Cataract in Owen County, the Elwren sandstone at Reelsville in Putnam County, the Reelsville and Beaver Bend formations a few miles farther north, the Paoli limestone west of Greencastle, the Mitchell limestone in the northwest corner of Putnam and the southwest corner of Montgomery County, and the Warsaw limestone at Sugar Creek a few miles farther north. Because of the irregularity of the pre-Pennsylvanian surface, however, most of these formations are locally absent in small areas south of their respective limits.

STRUCTURAL HISTORY

Many of the erosional unconformities and sedimentary hiatuses separating the Paleozoic formations of the central United States indicate only periodic oscillations of the epi-continental seas produced by extraneous diastrophism and gradual but irregular subsidence of the dominant basins of sedimentation. Other unconformities definitely reveal doming, folding, and faulting in and about such dominantly positive areas as the Ozark region, the Wisconsin and Lake Superior highlands, and the Cincinnati arch, all of which existed in the Ordovician period.

Pre-Mississippian deformation.—The oldest unconformity involved in a study of the Mississippian system in the Eastern Interior basin is the one at the base of the Devonian system. Either during or at the close of Silurian time both the Ozark region and the Cincinnati arch were gently domed and all Silurian beds were eroded and other strata as old as early Ordovician were locally exposed. Comparable deformation and erosion did not occur at this time along the Kankakee arch and LaSalle anticline in north-central Illinois.

At the close of the Middle Devonian time an extensive fault zone which has maximum relative displacement of about 1,000 feet in Ste. Genevieve County, Missouri, and which may extend an unknown distance eastward beneath the cover of younger formations was developed. Erosion in the uplifted Ozark region produced a peneplain by the beginning of the Mississippian period. Comparable deformation and erosion are not known to have occurred elsewhere in or about the Eastern Interior basin.

The extensive overlap of Mississippian strata upon much older beds in the Ozark region and northern Illinois as indicated by residual cherts and boulders of Osage age was largely the result of these two periods of erosion, whose effects are also apparent in the interior of the basin in the variable interval between the "Trenton" limestone and the base of the Mississippian system. The relations of the Mississippian system to older formations were largely determined by pre-Devonian or early Devonian erosion along the Cincinnati arch, along the north flank of the Ozarks, and probably also in northern Illinois, and by late Devonian erosion on the northeast flank of the Ozarks and in southwestern Illinois. None of the minor anticlines, synclines, or other structural features of the Eastern Interior basin can be traced to Devonian deformation.

Intra-Mississippian deformation.—Comparatively slight doming of the Ozark region occurred several times during the Mississippian period. The most important is indicated by the unconformity separat-

ing the Kinderhook series and the Osage group, which was followed by the great overlap of Osage on Ordovician beds. The Waterloo and Valmeyer anticlines were probably initiated at this time. Minor doming probably resulted in the unconformites in the Keokuk and between the St. Louis and Ste. Genevieve limestones in Ste. Genevieve County, Missouri. Doming of the Ozark region again occurred in the interval that separated Ste. Genevieve and Chester time, when the Waterloo and probably also the Valmeyer anticlines were greatly accentuated. Further minor doming of this same area led to the unconformity separating the Aux Vases and Renault formations in Monroe County, Illinois, and the overlap of the latter on lower Mississippian beds. Later minor movements were probably responsible for the local absence of several of the higher Chester formations along the southwestern margin of the basin in Missouri and Illinois. None of the other positive areas that bound the Eastern Interior basin give evidence of doming during the Mississippian period. All of the other Mississippian unconformites are apparently related simply to temporary emergent conditions.

Post-Mississippian deformations.—At the close of the Mississippian period the positive areas surrounding the Eastern Interior basin were all domed and subjected to erosion. Older structures, such as the Waterloo anticline, were accentuated and new structures, such as the LaSalle anticline and the Cap-au-Gres fault and flexure zone, were formed. Normal faulting on a small scale occurred in Union County, Illinois, and Hart County, Kentucky (10).

By middle Pottsville time, when Pennsylvanian sediments were first extensively deposited in the Eastern Interior basin, erosion had nearly peneplained this region and the Pennsylvanian overlapped Ordovician beds to the north. During the Pennsylvanian period the basin continued to subside progressively but not uniformly in response to loading, and some of the existing structures, notably the LaSalle anticline, were gradually accentuated.

Some time after the close of the Pennsylvanian period the Ozark region and the Cincinnati arch were again uplifted and domed to a greater extent than ever before and additional movement occurred along the LaSalle anticline, the Cap-au-Gres fault and flexure zone, and the Waterloo anticline. A great uplift with complicated faulting extending from beyond Ste. Genevieve County, Missouri, to at least Hart County, Kentucky, and the development of Hicks dome occurred in the southern part of the basin and the present southern boundary of the basin was formed.

An extended period of erosion followed, reducing the region to a

peneplain which was later warped and overlapped at the south by the Mississippi embayment deposits of late Cretaceous age. During Cenozoic time several slight regional warpings and changes in level occurred, and the southern part of the basin is not yet in complete equilibrium as indicated by earthquakes (of which the New Madrid disturbance in 1811 was an outstanding example), one or more tremors being experienced each year.

Nature of faulting.—The complex faulted area in the southern part of the Eastern Interior basin is remarkable in that it exists in the midst of a great region of nearly horizontal and undisturbed rocks. The faulting is generally considered to be the "normal" type but it is peculiar in several respects. Faults, some notably sinuous and all with high-angle fault planes, with some of which steeply dipping and even overturned beds are associated, occur in the fault zone extending from Ste. Genevieve County, Missouri, to Union County, Illinois, and in the Shawneetown-Rough Creek zone in southeastern Illinois and western Kentucky where locally the displacement is as great as and possibly much more than 3,500 feet (10, p. 59). Formations stratigraphically much lower than those extensively exposed near by are brought to the surface at a number of places. Faults of this type seem to have resulted from compressive rather than tensional stresses and are therefore probably high-angle thrust faults.

Another type of faulting with maximum displacements locally as great as 2,000 feet (94, p. 100) is excellently developed in the fluorspar district where a complicated mosaic pattern has resulted from the intersection of numerous nearly straight lines of displacement. The major faults roughly parallel each other and the blocks between them are cut by minor displacements commonly in a step-like manner. Some of the fault planes can be examined to a depth of 200–700 feet in fluorspar mines. Several of these are inclined first in one direction and then in another so that the terms "hanging-wall" and "footwall" can not be consistently applied. Slickensides indicate that movement along the faults has occurred at several different times and in several different directions, with complete reversal in some places. Most of the movements include an important horizontal component and some were nearly horizontal.

Vulcanism.—Intrusions of basic rock in the form of dikes, sills, and plugs crop out at several places in Hardin and Pope counties, Illinois, and Livingston, Crittenden, and Caldwell counties, Kentucky. Similar material has also been encountered in the fluorspar mines and in a coal mine on the northwest in Saline County, Illinois.

The association of igneous intrusions with fissure-vein deposits of

fluorspar accompanied by small amounts of argentiferous galena indicates hydrothermal mineralization and suggests that the post-Pennsylvanian uplift which now forms the southern boundary of the Eastern Interior basin resulted from a deep-seated igneous intrusion of considerable extent and that the faulting was produced by compression about the borders of the intruded mass and tension of the arched strata which it upraised. Subsequent cooling and shrinkage of the igneous material might explain the minor readjustments that continue to the present day.

OIL AND GAS FORMATIONS

Illinois.—Production of oil or gas is being or has been obtained from several horizons in the Mississippian system in Bond, Clark, Clay, Clinton, Coles, Crawford, Edwards, Fayette, Franklin, Gallatin, Hamilton, Jackson, Jasper, Jefferson, Lawrence, Marion, Morgan, Randolph, Richland, Shelby, Wabash, Washington, Wayne, and White counties. The most widely productive beds are in the lower part of the Chester series as follows.

Palestine sandstone: Wabash County.

Waltersburg sandstone: Gallatin and White counties.

Tar Springs sandstone: Wabash County; 600-foot Froemling sand of Jackson County.

Sandstone member of Golconda formation: "Gas" sand of Lawrence County.

Cypress sandstone: Edwards, Marion, and Wabash counties; Weiler sand of Clinton, Coles, Fayette, Marion, Richland, and Wabash counties; Carlyle sand of Clinton County; Kirkwood sand of Lawrence County; Bellair 900-foot sand of Crawford and Jasper counties; 800-foot Froemling sand of Jackson County; upper Lindley sand of Bond County; Sparta gas sand of Randolph County.

Sandstone member of Paint Creek formation: Stray sand of Fayette County.

Bethel sandstone: White County; Benoist sand of Clinton, Fayette, Jefferson, Marion, and Wabash counties; Tracey sand of Lawrence County.

The so-called Aux Vases sand of Clay, Marion, Shelby, Wayne, and White counties and possibly the Bradley sand of Wayne County and the lower Lindley sand of Bond County are probably the subsurface equivalent of the Hoffner member of the Ste. Genevieve formation known in outcrop in Union County.

A considerable proportion of the oil produced in Illinois has been obtained from porous beds occurring at several horizons in the Meramec limestones, especially in the Ste. Genevieve formation. The latter have been commonly referred to as the McClosky "sand," actually a porous oölite. Records of the McClosky wells in Lawrence County are so incomplete that the precise position of the producing horizon, the original McClosky "sand" (and Oblong "sand" of Crawford County), in the upper part of the Ste. Genevieve formation can

not be determined. Most of the recent McClosky production of Clay, Edwards, Franklin, Jefferson, Marion, Richland, Wabash, Wayne, and White counties is obtained a short distance below the Rosiclare sandstone member, which is itself productive in Jefferson County and elsewhere in the central basin fields. The main producing "sand" of the Martinsville pool in Clark County is either in the lower part of the Ste. Genevieve or the upper part of the St. Louis limestone. A still lower horizon in the Martinsville pool and a horizon of small production recently developed in Franklin and Jefferson counties are probably in the St. Louis limestone. Small amounts of oil and gas have been obtained from the Mississippian limestone just beneath the pre-Pennsylvanian unconformity in Morgan County at either the top of the Salem or the base of the St. Louis limestone. A few wells in the Salem pool of Marion County produce from the Salem limestone. Showings from Meramec limestones have been reported in Edgar, Clark, Coles, and Cumberland counties.

The Carper sand of the Martinsville pool is the only producing formation in the Osage group. Showings at a similar horizon are reported also in the Westfield pool, and other Osage showings have been encountered in Fulton, Morgan, Schuyler, and Union counties.

Indiana.—The main producing formations in the Mississippian system of Indiana are as follows.

Tar Springs sandstone: Colvier, Davidson deep, Loveless sands
Hardinsburg sandstone: Buchanan, Hightower shallow, Hoover gas sand
Cypress sandstone:[36] Cunningham shallow, Hoover oil, Hyneman, Zimmerman sands
Elwren sandstone: Barker, Snyder shallow, Willis sands
Bethel (Sample) sandstone: Cunningham deep, Hunt, Mixon sands
Mooretown sandstone: Hightower deep, Kirkwood, Oakland City, Petersburg Snyder deep sands
Paoli limestone: Brown, Monroe City deep, Tracy, Vierling "sands"

More or less good showings have been reported from several deeper beds and the New Albany shale has yielded gas in Harrison County.

Kentucky.—In western Kentucky the main producing formations of the Mississippian are as follows.

Upper Chester sandstones: Stray sands
Tar Springs sandstones: Jett or Stevens sand
Hardinsburg sandstone: Jones sand
Cypress sandstone:[36] Jackson sand
Elwren sandstone: Barlow sand

[36] Recent subsurface studies suggest that the Cypress sandstone as identified in Indiana and in the subsurface of western Kentucky is the mid-Golconda sand known as the "Gas" sand in the Lawrence County field of Illinois (P. L. Dana and E. H. Scobey, "A Cross-Section of the Chester Series of the Illinois Basin" read before the Am. Assoc. Petrol. Geol., April 11, 1940). If this suggested correlation is correct correlations of the lower Chester producing sands in Indiana and Kentucky probably also require adjustment.

Mooretown sandstone: Bethel sand
Ste. Genevieve: McClosky "sand"
St. Louis: Major; Warren County shallow "sands"

Small amounts of oil and gas have been encountered at several depths in the Osage group in various parts of Breckenridge and Grayson counties. In Meade and Hardin counties the New Albany shale and overlying strata yield gas.

BIBLIOGRAPHY

The following bibliography is incomplete but contains all the recent more important articles relating to the Mississippian system in the Eastern Interior basin and from them references to most of the older literature may be obtained. The titles of several unpublished manuscripts which have been consulted in the preparation of this paper are also listed.

1. BAIN, H. F., "Geology of Washington County," *Iowa Geol. Survey*, Vol. 5, pp. 117–172, 1896.
2. BEEDE, J. W., "Geology of the Bloomington Quadrangle," *Indiana Dept. Geol. and Nat. Res. Ann. Rept. 39*, pp. 190–216, 1915.
3. BRANSON, E. B., and MEHL, M. G., "Conodonts from the Grassy Creek Shale of Missouri," *Univ. Missouri Studies*, Vol. 8, pp. 171–259, 1933.
4. BRANSON, E. B., and others, "Stratigraphy and Paleontology of the Lower Mississippian of Missouri, Parts I and II," *Univ. Missouri Studies*, Vol. 13, Nos. 3 and 4, 1938.
5. BRANSON, E. B., "Conodonts from the Hannibal Formation of Missouri," *Univ. Missouri Studies*, Vol. 8, pp. 301–343, 1933.
6. BUTTS, CHARLES, "Geology and Mineral Resources of Jefferson County, Kentucky," *Kentucky Geol. Survey, Ser. 4*, Vol. 3, Pt. 2, 270 pp., 1915.
7. ———, "Descriptions and Correlations of the Mississippian Formations of Western Kentucky," *Kentucky Geol. Survey, Ser. 4, Mississippian Formations of Western Kentucky*, pp. 1–119, 1917.
8. ———, "Geology of Barren County, Kentucky (Reconnaissance Geologic Map)," *Kentucky Geol. Survey, Ser. 5*, Vol. 1, pp. 147–177, 1919.
9. ———, "The Mississippian Series of Eastern Kentucky," *Kentucky Geol. Survey, Ser. 6*, Vol. 7, 188 pp., 1922.
10. ———, "Geology and Mineral Resources of the Equality-Shawneetown Area," *Illinois State Geol. Survey Bull. 47*, 76 pp., 1925.
11. ———, "Geology of Alabama: The Paleozoic Rocks," *Alabama Geol. Survey, Spec. Rept. No. 14*, pp. 41–230, 1926.
12. Calvin, Samuel, "Discussion of Weller's Correlation of the Middle and Upper Devonian and the Mississippian Faunas of North America," *Jour. Geol.*, Vol. 17, p. 285, 1909.
13. ———, "Introduction to the Geology of Quarry Products," by S. W. Beyer and I. A. Williams, *Geol. Survey of Iowa*, Vol. 17, pp. 192–200, 1907.
14. CORYELL, H. N., "Parts of Pike and Adams Counties," *Illinois State Geol. Survey Bull. 40*, pp. 69–95, 1919.
15. CRONEIS, CAREY, "Geology of the Arkansas Paleozoic Area," *Arkansas Geol. Survey Bull. 3*, 1930.
16. CUMINGS, E. R., "The Nomenclature and Description of the Geological Formations of Indiana," *Indiana Dept. Conservation Pub. 21*, pp. 403–571, 1922.
17. DAVIS, W. W., "Evidence Bearing on a Possible Northward Extension of the Mississippian Seas in Illinois," *Jour. Geol.*, Vol. 25, pp. 576–583, 1917.
18. EKBLAW, G. E., "Post-Chester, pre-Pennsylvanian Faulting in the Alto Pass Area," *Trans. Illinois State Acad. Sci.*, Vol. 18, pp. 378–382, 1925.
19. FENNEMAN, N. M., "Geology and Mineral Resources of the St. Louis Quadrangle, Missouri-Illinois," *U. S. Geol. Survey Bull. 438*, 1911.

20. FLINT, R. F., "The Geology of Parts of Perry and Cape Girardeau Counties, Missouri," *Missouri Bur. Geol. and Mines*, Mss.
21. GLENN, L. C., and MCFARLAN, A. C., "Geological Map of Butler County, Kentucky", *Kentucky Geol. Survey*, Ser. 6, 1928.
22. HALL, JAMES, "Observations upon the Carboniferous Limestones of the Mississippi Valley," *Amer. Jour. Sci.*, Ser. 2, Vol. 23, pp. 187–203, 1857.
23. ———, Report of the Geological Survey of Iowa, Vol. 1, 1858.
24. HARRELL, M. A., "Ground Water in Indiana," *Indiana Dept. Conservation Pub. 133*, 1935.
25. JILLSON, W. R., "Early Carbonic Deformation in Western Kentucky," *Pan-Amer. Geol.*, Vol. 49, pp. 357–358, 1928; *Kentucky Geol. Survey*, Ser. 6, Vol. 35, pp. 273–275, 1930.
26. ———, "Structural Geologic Map of Kentucky," *Kentucky Geol. Survey*, Ser. 6, 1931.
27. KEYES, C. R., "Geology of Lee County," *Iowa Geol. Survey*, Vol. 3, pp. 305–407, 1895.
28. ———, "Some Geological Formations of the Cap-au-Gres Uplift," *Proc. Iowa Acad. Sci.*, Vol. 5, pp. 58–63, 1898.
29. ———, "Marked Unconformity between Carboniferous and Devonian Strata in Upper Mississippi Valley," *Amer. Jour. Sci.*, Ser. 4, Vol. 36, pp. 160–164, 1913.
30. KREY, F. F., "Structural Reconnaissance of the Mississippi Valley Area from Old Monroe, Missouri, to Nauvoo, Illinois," *Illinois State Geol. Survey Bull. 45*, 85 pp., 1924; *Missouri Bur. Geol. and Mines*, Ser. 2, Vol. 8, 86 pp., 1924.
31. ———, "Geology of the Dongola Quadrangle," *Illinois State Geol. Survey*, Mss.
32. LAMAR, J. E., "Geology and Mineral Resources of the Carbondale Quadrangle," *Illinois State Geol. Survey Bull. 48*, 172 pp., 1925.
33. LAUDON, L. A., "Stratigraphy of the Kinderhook Series of Iowa," *Iowa Geol. Survey*, Vol. 25, pp. 333–451, 1931.
34. ———, "Stratigraphy of the Northern Extension of Burlington Limestone in Missouri and Iowa," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, pp. 1158–1167, 1937.
35. LOGAN, W. N., "The Economic Geology of Indiana," *Indiana Dept. Conservation Publication 21*, pp. 571–1058, 1922.
36. MCCARTNEY, G. C., "A Petrographic Study of the Chester Sandstones of Indiana," *Jour. Sed. Petrol.*, Vol. 1, pp. 82–90, 1931.
37. MALOTT, C. A., "The Upper Chester of Indiana," *Proc. Indiana Acad. Sci.*, Vol. 34, pp. 103–132, 1925.
38. ———, "Geologic Structure in the Indian and Trinity Springs Locality," *Proc. Indiana Acad. Sci.*, Vol. 40, pp. 217–231, 1931.
39. MAYFIELD, S. M., "Geology of the Fordsville and Cannelton Quadrangles," *Kentucky Geol. Survey*, Mss.
40. MILLER, RAYMOND, and CRABB, D. H., "Geologic Map of Simpson County, Kentucky," *Kentucky Geol. Survey*, 1930.
41. MOORE, R. C., "Early Mississippian Formations of Missouri," *Missouri Bur. Geol. and Mines*, Ser. 2, Vol. 21, 283 pp., 1929.
42. ———, *Historical Geology*, McGraw-Hill Book Co., New York, 673 pp. 1933.
43. ———, "Mississippian System in the Upper Mississippi Valley," *Kansas Geol. Soc. Guidebook 9th Ann. Field Confer.*, pp. 239–245, 1935.
44. ———, "Comparison of the Carboniferous and Early Permian Rocks of North America and Europe", 2nd Congrès pour l'avancement des études de stratigraphie Carbonifére, Heerland, *Compte rendu*, pp. 641–676, 1937.
45. MORSE, W. C., "Paleozoic Rocks," *Mississippi State Geol. Survey Bull. 23*, 1930.
46. NORTON, W. H., and others, "Underground Water Resources of Iowa," *Iowa Geol. Survey*, Vol. 21, pp. 29–1214, 1912.
46a. PAYNE, J. N., "Subsurface Geology of Iowa (Lower Mississippian) Series in Illinois," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, pp. 225–236, 1940.
47. ROWLEY, R. R., "The Geology of Pike County," *Missouri Bur. Geol. and Mines*, Ser. 2, Vol. 8, 122 pp., 1908.
48. RUBY, W. W., "Geology and Mineral Resources of the Hardin and Brussels Quadrangles in Illinois," *Illinois State Geol. Survey*, Mss.
49. RUSSELL, W. L., "Geology of Oil and Gas Fields of Western Kentucky," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, pp. 231–254, 1932.

50. SAVAGE, T. E., "Devonian Formations of Illinois," *Amer. Jour. Sci.*, Ser. 4, Vol. 49, pp. 169–182, 1920.
51. ———, "The Devonian Rocks of Kentucky," *Kentucky Geol. Survey*, Ser. 6, Vol. 33, pp. 1–161, 1930.
52. ———, and SUTTON, A. H., "Age of the Black Shale in South-Central Kentucky," *Am. Jour. Sci.*, Ser. 5, Vol. 22, pp. 441–448, 1931.
53. ———, "Geology of the Jonesboro Quadrangle," *Illinois State Geol. Survey*, Mss.
54. STOCKDALE, P. B., "The Borden (Knobstone) Rocks of Southern Indiana," *Indiana Dept. Conservation Pub. 98*, 1931.
54a. ———, "Lower Mississippian Rocks of the East-Central Interior," *Geol. Soc. Amer.*, Special Paper 22, 248 pp. 1939.
55. STOUDER, R. E., "Chester Rocks of Meade, Hardin, and Breckenridge Counties, Kentucky," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, pp. 267–284, 1938.
56. SUTTON, A. H., "Geology of the Southern Part of the Dawson Springs Quadrangle," *Kentucky Geol. Survey*, Ser. 6, Vol. 31, pp. 169–280, 1929.
57. ———, and WAGNER, O. E., "Geological Map of Meade County," *Kentucky Geol. Survey*, Ser. 6, 1930.
58. ———, "A Reconnaissance Survey of the Geology of Northern Hardin County," *Kentucky Geol. Survey*, Ser. 6, Vol. 37, pp. 267–299, 1931.
59. ———, "Stratigraphy of the Okaw in Southwestern Illinois, "*Jour. Geol.*, Vol. 42, pp. 621–629, 1934.
60. ———, "Geology of the Smithland and Eddyville Quadrangles," *Kentucky Geol. Survey*, Mss.
61. ———, and WELLER, J. M., "Lower Chester Correlations in Western Kentucky and Illinois," *Jour. Geol.*, Vol. 40, pp. 430–442, 1932.
62. UDDEN, J. A., "Geology of Muscatine County," *Iowa Geol. Survey*, Vol. 9, pp. 247–380, 1899.
63. ULRICH, E. O., in "The Quarrying Industry of Missouri" by E. R. Buckley and H. A. Buehler, *Missouri Bur. Geol. and Mines*, Ser. 2, Vol. 2, pp. 109–111, 1904.
64. ———, "The Lead, Zinc, and Fluorspar Deposits of Western Kentucky: Geology and General Relations," *U. S. Geol. Survey Prof. Paper 36*, pp. 7–105, 1905.
65. ———, "Revision of the Paleozoic Systems," *Bull. Geol. Soc. Amer.*, Vol. 22, pp. 281–680, 1911.
66. ———, "The Formations of the Chester Series in Western Kentucky and Their Correlatives Elsewhere," *Kentucky Geol. Survey*, Ser. 4, Mississippian Formations of Western Kentucky, pp. 121–272, 1917.
67. VAN TUYL, F. M., "The Stratigraphy of the Mississippian Formations of Iowa," *Iowa Geol. Survey*, Vol. 30, pp. 33–374, 1925.
68. WELLER, J. M., "The Geology of Edmonson County," *Kentucky Geol. Survey*, Ser. 6, Vol. 28, 246 pp., 1927.
69. ———, "Geological Map of Edmonson County," *Kentucky Geol. Survey*, Ser. 6, 1929.
70. ———, "Paleontology of Kentucky: Paleontology of the Mississippian System," *Kentucky Geol. Survey*, Ser. 6, Vol. 36, pp. 251–291, 1931.
71. ———, "Geology of the Campbell Hill Quadrangle," *Illinois State Geol. Survey*, Mss.
72. ———, "The Warsaw Formation," *Illinois State Acad. Sci. Trans.*, Vol. 26, p. 106, 1934.
73. ———, "Grassy Creek Shale," *Illinois State Acad. Sci. Trans.*, Vol. 28, pp. 191–192, 1935.
74. ———, "Geology and Oil Possibilities of the Illinois Basin," *Illinois State Geol. Survey*, Illinois Petrol., No. 27, 1936.
75. ———, and BELL, A. H., "Illinois Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, pp. 771–788, 1937.
75a. ———, "Mississippian System," *Kan. Geol. Soc. Guide Book 13th Ann. Field Confer.*, pp. 131–137, 1939.
75b. ———, "Geologic Map of Illinois," *Ill. State Geol. Surv.*, blue-line print, 1939.
76. WELLER, STUART, "Kinderhook Faunal Studies II, The Fauna of the *Chonopectus* Sandstone at Burlington, Iowa," *Trans. Acad. Sci. St. Louis*, Vol. 10, pp. 57–129, 1900.
77. ———, "The Succession of Fossil Faunas in the Kinderhook Beds at Burlington, Iowa," *Iowa Geol. Survey*, Vol. 10, pp. 61–81, 1900.

78. ———, "Kinderhook Faunal Studies III, The Faunas of Beds No. 3 to No. 7 at Burlington, Iowa," *Trans. Acad. Sci. St. Louis*, Vol. 11, pp. 147–214, 1901.
79. ———, "Kinderhook Faunal Studies IV, The Fauna of the Glen Park Limestone," *Trans. Acad. Sci. St. Louis*, Vol. 6, pp. 435–471, 1906.
80. ———, "Notes on the Geology of Southern Calhoun County," *Illinois State Geol. Survey Bull. 4*, pp. 219–233, 1907.
81. ———, "The Salem Limestone," *Illinois State Geol. Survey Bull. 8*, pp. 81–102, 1908.
82. ———, "Correlation of the Middle and Upper Devonian and the Mississippian Faunas of North America," *Jour. Geol.*, Vol. 17, pp. 257–284, 1909.
83. ———, "Kinderhook Faunal Studies V, The Fauna of the Fern Glen Formation," *Bull. Geol. Soc. Amer.*, Vol. 20, pp. 265–332, 1909.
84. ———, "Stratigraphy of the Chester Group in Southwestern Illinois," *Trans. Illinois State Acad. Sci.*, Vol. 6, pp. 118–129, 1913.
85. ———, "The Mississippian Brachiopoda of the Mississippi Valley Basin," *Illinois State Geol. Survey Monogr. 1*, 508 pp., 1914.
86. ———, "The Chester Series in Illinois," *Jour. Geol.*, Vol. 28, pp. 281–303, 395–416, 1920.
87. ———, and others, "The Geology of Hardin County and the Adjoining Part of Pope County," *Illinois State Geol. Survey Bull. 41*, 416 pp., 1920.
88. ———, "Geology of the Golconda Quadrangle," *Kentucky Geol. Survey*, Ser. 6, 148 pp., 1921.
89. ———, and ST. CLAIR, STUART, "Geological Map of Ste. Genevieve County and Parts of Perry and St. Francois Counties," *Missouri Bur. Geol. and Mines*, 1922. Also included with report on Ste. Genevieve County, see No. 96.
90. ———, "Geology of the Princeton Quadrangle," *Kentucky Geol. Survey*, Ser. 6, Vol. 10, pp. 1–105, 1923.
91. ———, "Map of the Structural Geology of the Golconda and Cave in Rock Quadrangles in Kentucky," *Kentucky Geol. Survey*, Ser. 6, 1925.
92. ———, "Faunal Zones of the Standard Mississippian Section," *Jour. Geol.*, Vol. 34, pp. 320–335, 1926.
93. ———, and others, "Map of the Areal and Structural Geology of Livingston County, Kentucky," *Kentucky Geol. Survey*, Ser. 6, 1926.
94. ———, "Geology of the Cave in Rock Quadrangle," *Kentucky Geol. Survey*, Ser. 6, Vol. 26, pp. 1–128, 1927.
95. ———, SUTTON, A. H., and CRIDER, A. F., "Map of the Areal and Structural Geology of Caldwell County, Kentucky," *Kentucky Geol. Survey*, Ser. 6, 1927.
96. ———, and ST. CLAIR, STUART, "The Geology of Ste. Genevieve County, Missouri," *Missouri Bur. Geol. and Mines*, Ser. 2, Vol. 22, 352 pp., 1928.
97. ———, and SUTTON, A. H., "Map of the Areal and Structural Geology of Crittenden County, Kentucky," *Kentucky Geol. Survey*, Ser. 6, 1929.
98. ———, "Geology of Parts of Monroe and Randolph Counties," *Illinois State Geol. Survey*, Mss.
99. ———, "Geology of Parts of Johnson and Pope Counties," *Illinois State Geol. Survey*, Mss.
99a. ———, and WELLER, J. M., "Preliminary Geological Maps of the Pre-Pennsylvanian Formations in part of Southwestern Illinois"; Explanation and Stratigraphic Summary by J. M. Weller, *Illinois State Geol. Survey Rept. Invest. 59*, 1939.
99b. ——— and KREY, F. F., "Preliminary Geological Map of the Mississippian Formations in the Dougola, Vienna, and Brownfield Quadrangles"; Explanation and Stratigraphic Summary by J. M. Weller, *Illinois State Geol. Survey Rept. Invest. 60*, 1939.
100. WITHERS, S., SUTTON, A. H., WESLEY, G., and CRABB, D., "Reconnaissance Geological Map of Hart County, Kentucky, *Kentucky Geol. Survey*, Ser. 6, 1931.
101. WOODRUFF, J. G., "Map of the Areal and Structural Geology of Muhlenberg County, Kentucky," *Kentucky Geol. Survey*, Ser. 6, 1930.
102. WORKMAN, L. E., "Subsurface Geology of Chester Series in Illinois," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, pp. 209–224, 1940.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 5 (MAY, 1940), PP. 859-881, 11 FIGS.

GEOCHEMICAL EXPLORATION (SOIL ANALYSIS)

WITH SOME SPECULATION ABOUT THE GENESIS OF OIL, GAS, AND OTHER MINERAL ACCUMULATIONS[1]

EUGENE McDERMOTT[2]
Dallas, Texas

ABSTRACT

The newly developed methods of geochemical exploration will undoubtedly play an important rôle in exploration for oil and gas fields. There has been a tendency in this country among the explorers for oil and gas to undervalue the rôle of surface evidences of such deposits. Most of the great oil fields of the world have been indicated by surface evidences. In view of the prevalence of visible oil and gas seeps it is reasonable to expect to find microscopic seeps in much greater abundance. In practically all cases maximum leakage occurs from the edges of accumulations. These leaking gases are adsorbed by the earth particles near the surface and are then polymerized to the heavier hydrocarbons. The gases in leaking to the surface transport quantities of subsurface waters and the dissolved minerals, resulting in many cases in high mineral concentrations near the surface.

The data of geochemistry have led to some very interesting speculations regarding the genesis of oil and gas fields. Evidence strongly suggests that oil and gas fields result from the polymerization of the migrating hydrocarbon gases. Two sources of such gases have been measured, namely, vegetable matter that is being devolatilized and the basement rocks. There may of course be others as yet unmeasured. The important consideration is that so far as migration is concerned the gases are the principal participants.

It is believed that the oil accumulations and the concentrations of adsorbed hydrocarbons in the soil and in the oil shales are genetically related. As the principal difference between marine and non-marine sediments is the presence of sodium chloride (not organic content according to Trask), and as this will act as a catalytic agent to polymerize the hydrocarbon gases, it is reasonable to suppose that this is why oil fields occur in marine rather than non-marine sediments. Experimental laboratory investigation verifies this.

If one goes back far enough in point of origin of the organic gases either in the buried vegetable matter or the basement rocks both origins would immediately become inorganic. In view of this can it be said that there has ever been an organic theory of the origin of oil and gas?

On the basis of the hypothesis proposed it is possible to explain the difference in mineralization of subsurface waters in different geologic provinces, as well as the relation between volatility of accumulations as a function of the carbon ratio (rock deformation) and overburden. Caliche may owe its existence to the transporting power of the vertically migrating gases.

It should be kept in mind the method of geochemical exploration is not predicated on the theoretical conceptions here presented. Rather, the reverse is true, in that the theory is derived from the data of geochemistry.

METHOD OF EXPLORATION

The newly developed method of geochemical exploration will undoubtedly play an important rôle in exploration for oil and gas fields.

There has been a tendency in this country among the explorers for oil and gas to undervalue the rôle of surface evidences of the buried accumulations such as oil and gas seeps and the secondary effects of

[1] Read before the Association at Chicago, April, 1940. Manuscript received, March 15, 1940.

[2] President, Geophysical Service, Inc.

those seeps such as mineralization phenomena. Such evidences have played a very important part in the discovery of oil and gas pools during a long period of the history of exploration in this country and are still an important factor in the discoveries now being made elsewhere all over the world.

To quote from a well known English authority, A. Beeby Thompson,[3]

> An attempt is made in this short paper to show that surface indications of oil are a natural and essential phenomenon connected with oilfields rather than an unusual circumstance, and further that failure to discern such manifestations is either damaging to prospects or a reflection upon our present-day knowledge of detecting signs of the past escape of hydrocarbons. . . .
>
> Old-time prospectors were largely influenced in their choice of sites for drilling by the extent and distribution of such positive evidences of oil. . . .
>
> With the exception of some of the oilfields of the Eastern, Mid-Continental and Rocky Mountain States of U. S. A., practically all the great oilfields of the world were marked by oil and gas issues near the crests of anticlines or the apices of domes. . . .

Sawtelle[4] shows that of the 141 salt domes discovered in the Gulf Coast prior to 1936, 75 owed their discovery, in part at least, to the presence of gas or oil seeps or mineralization phenomena. This is a surprisingly large percentage in view of the crude methods of detecting such evidences. The gas seeps had to be large and probably under water to permit detection, and the detection of mineralization phenomena depended on the chance location of water wells.

The methods of geochemical exploration permit the quantitative measurement of microscopic gas and oil seeps and mineralization phenomena that can not be detected visually. Furthermore, such measurements may be made at predetermined locations.

In view of the prevalence of visible oil and gas seeps, that is, leakage from buried accumulations, it is only reasonable to expect a much greater occurrence of microscopic leakage. The data of geochemistry amply verify this expectation. Leakage of various constituents from buried accumulations of oil and gas has been measured over many known fields. Sufficient data have been collected to anticipate the occurrence of leakage from practically all buried accumulations.

Of the geophysical methods of exploration, the reflection seismograph over the last 10 years has proved itself the most effective, and has to its credit a large number of oil and gas fields in many parts of

[3] A. Beeby Thompson, "The Economic Value of Surface Petroleum Manifestations," *Proc. World Petrol. Congress*, London (1933).

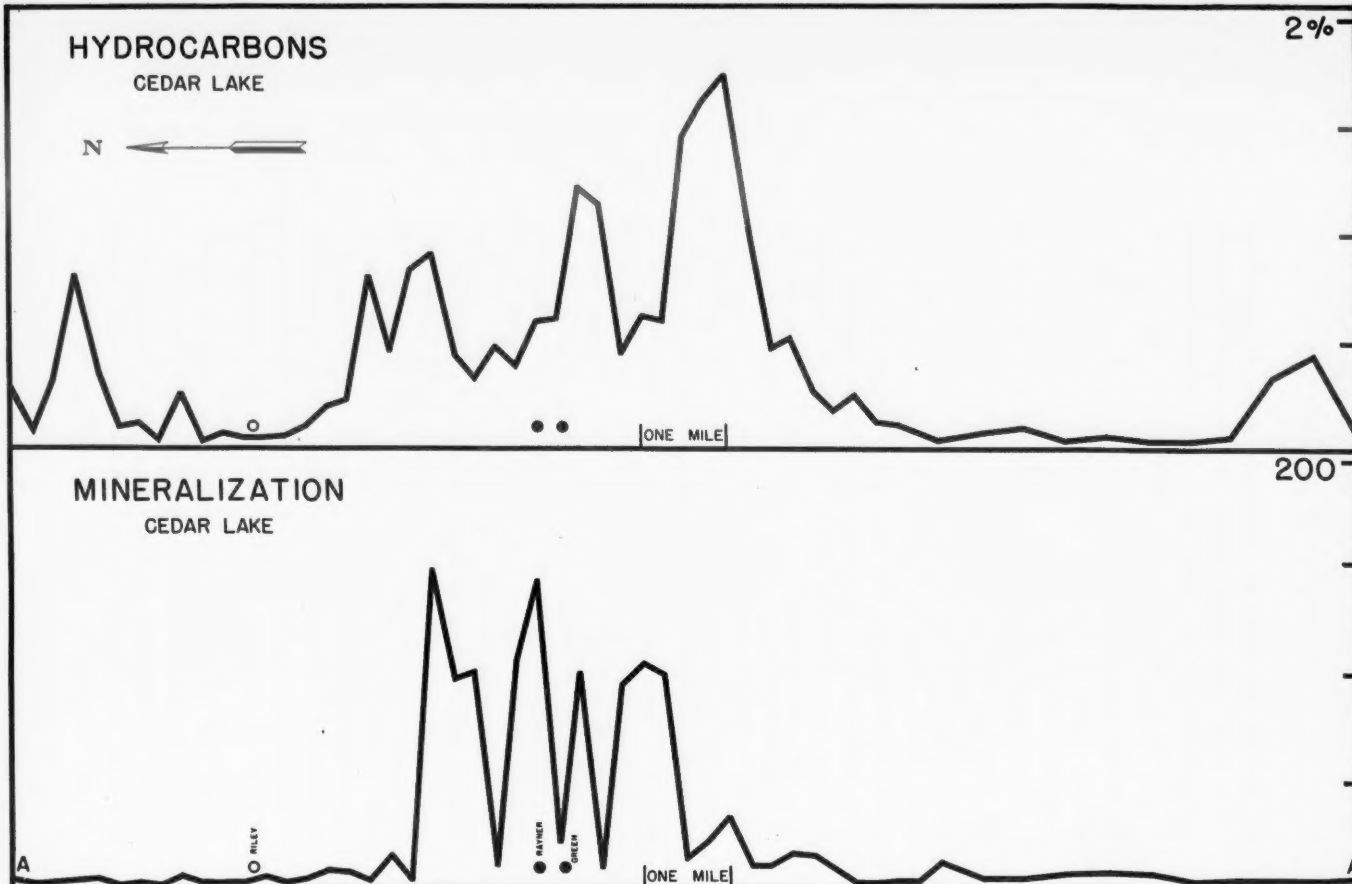
[4] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 6 (June, 1936) pp. 726–35.

this country and in foreign countries. The gravity meter has been a useful exploration tool in certain limited areas. Other geophysical methods of exploration, magnetic and electrical, have had a much more limited field of usefulness and, consequently, do not have many discoveries to their credit. The newer method of geochemical exploration should supplement these other methods and under certain conditions will be applicable where the other mentioned geophysical methods have been unsuccessful.

It has been found that in practically all cases, the maximum leakage from a buried oil or gas accumulation occurs over the edges of the accumulation rather than over the top. This, with other observations, has led to a rather interesting theory of the origin and accumulation of oil and gas. It is believed that the gaseous constituents of an oil accumulation are the most likely to escape and find their way to the earth's surface. Evidence justifies the assumption that the earth is replete with microscopic fissures which permit the gases to migrate from the buried accumulation to the surface. These hydrocarbon gases en route to the surface will be adsorbed by the earth materials. By taking samples of the earth just below the surface, say 10 feet, and quantitatively measuring the amount of adsorbed gas, it is possible to determine the areas of high concentrations and consequently the location of the buried oil or gas accumulation—the oil field to be.

Some of these hydrocarbon gases that are adsorbed on the earth particles will polymerize—grow into heavier hydrocarbons, that is, liquids and solids—which will remain on the earth particles. Instead of measuring the gases, therefore, the heavier hydrocarbons thus formed may be measured. Some of these heavy hydrocarbons are found to be most desirable for exploration purposes as they occur in much larger quantities than the lighter gases. Also, components may be measured which may be separated from contamination due to buried organic matter. A solid hydrocarbon or wax occurs immediately on the surface—due in all probability to the photosynthetic effect of sunlight. This is not regarded as a reliable constituent as it is affected by surface disturbances and contamination. The unsaturated gases such as ethylene are of course much more reactive than the saturated gases such as methane or ethane, and there is evidence that such gases are leaking through the earth.

Mineral concentrations are found to occur near the surface where the gaseous and heavier hydrocarbon concentrations occur. The mineral concentrations are secondary in nature and as they do not always occur they are, therefore, not nearly as valuable from an exploration viewpoint as the hydrocarbons. Such mineral concentrations are due



CEDAR LAKE FIELD, GAINES COUNTY, TEXAS

FIG. 1

to the fact that the gases in leaking to the surface will transport to the surface quantities of the mineralized subsurface waters. Upon reaching the surface the water will evaporate, leaving concentrations of minerals at and near the surface. Also the mineral patterns may be affected by surface contamination.

Attention is called to the fact that the geochemical method of exploration is the first valid direct method of exploration developed to date. That is, it locates the buried accumulation by measuring leakage from it. All other successful methods of exploration have in general measured physical or structural anomalies in the earth. The electrical method will measure chemical anomalies as well. As the conductivity of the earth is a function of the electrolyte in the earth pore spaces, an electrical survey might indicate the presence of the mineral concentrations previously mentioned. However, an additional variable is introduced as the conductivity of the earth is dependent on the amount of water present as well as the quantity of dissolved minerals.

A density of at least four analyses per square mile is necessary for a reconnaissance survey. For detail, eight analyses per square mile are in general sufficient.

FIELD DATA

The general procedure in developing and evaluating techniques was to make measurements on samples collected over a number of known oil fields in different areas. Some of these data are herewith presented.

A north-south section, 16 miles long, across the Cedar Lake field in Gaines County, Texas, is shown in Figure 1. Both hydrocarbons and mineralization are shown. Attention is called to the very high concentrations as compared with background values. In Figures 2 and 3 are shown maps of the area surveyed indicating both hydrocarbons and mineralization. The section of Figure 1 is marked *AA* on the maps. The cross-hatched values average 7.5 times average background values in the case of the hydrocarbons and 24.7 times in the case of the minerals. Altogether, 270 locations were analyzed. The locations are spaced at $\frac{1}{4}$-mile intervals in the immediate vicinity of the field and at $\frac{1}{2}$-mile intervals south of the field. The survey was made after the completion of the discovery well, the Stanolind's Raynor. Since then three offset wells have been completed. The Stanolind's Riley, 3 miles northwest of the discovery, was predicted as a dry hole or at best a possible edge well.

Figure 4 shows a west-east section across the Monument field and the south edge of Hobbs. The section shown is 19 miles long. An additional 35 miles of line toward the west was negative and substantiated the background values shown on the section.

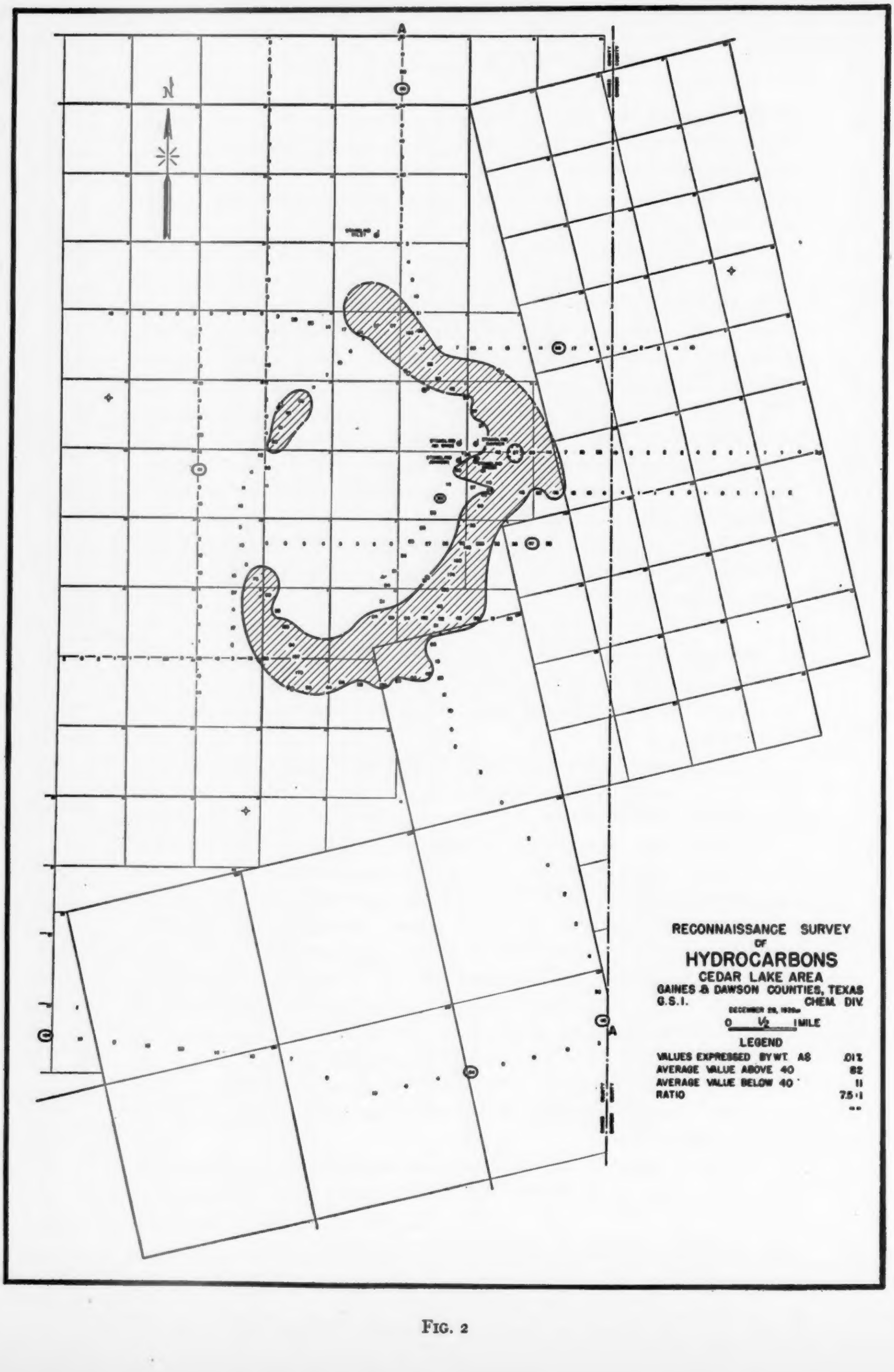

A
N
RECONNAISSANCE SURVEY
OF
HYDROCARBONS
CEDAR LAKE AREA
GAINES & DAWSON COUNTIES, TEXAS
G.S.I.
CHEM. DIV.
0 1/2 1 MILE
LEGEND
VALUES EXPRESSED BY WT. AS .01%
AVERAGE VALUE ABOVE 40 82
AVERAGE VALUE BELOW 40 11
RATIO 7.5:1

FIG. 2

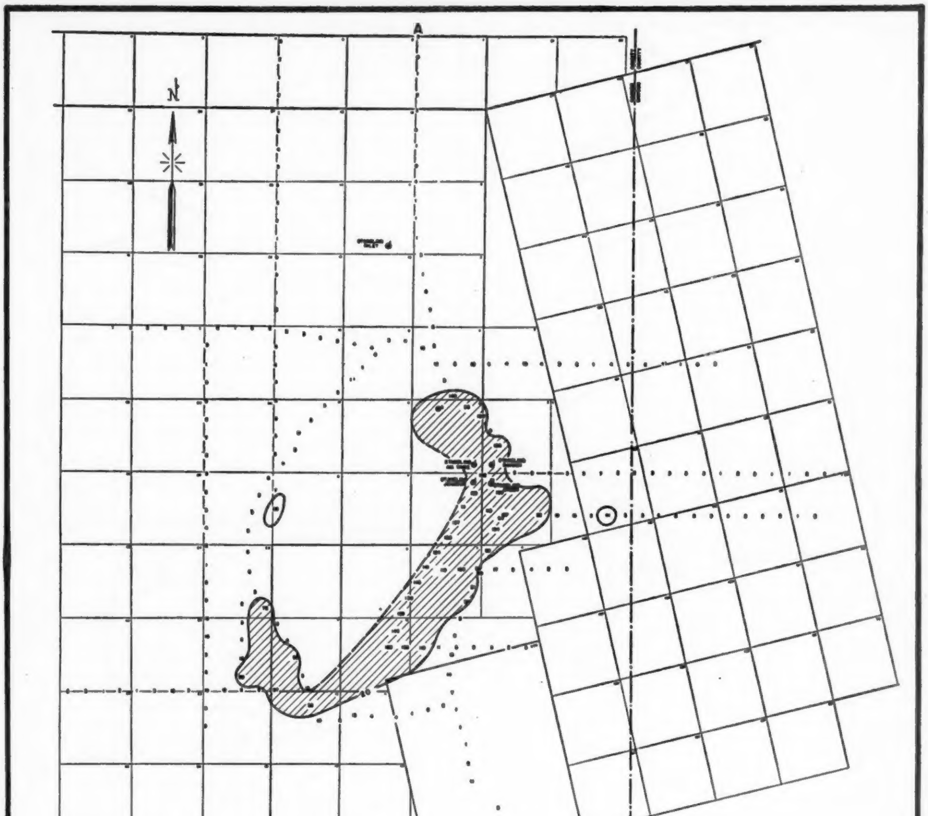
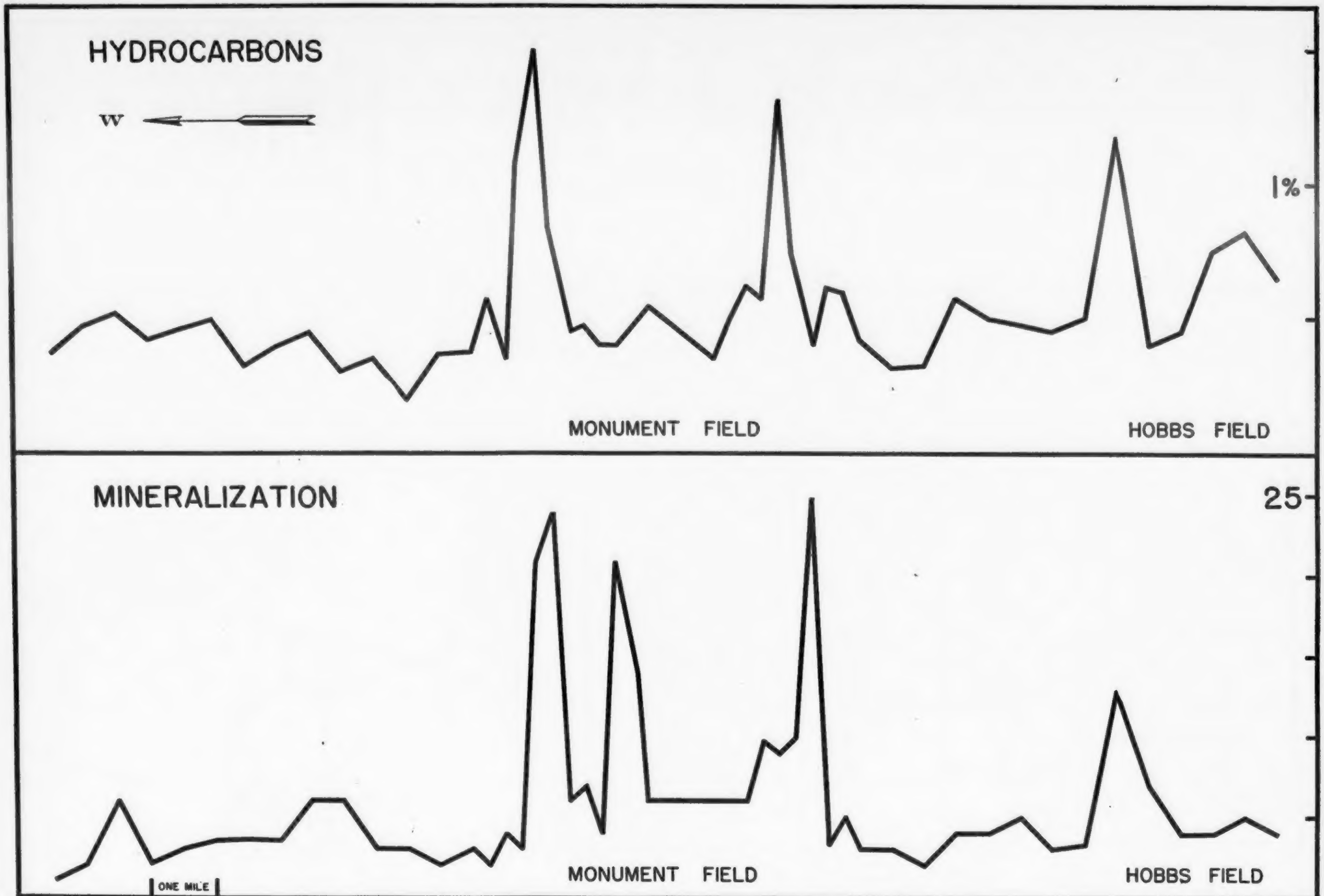
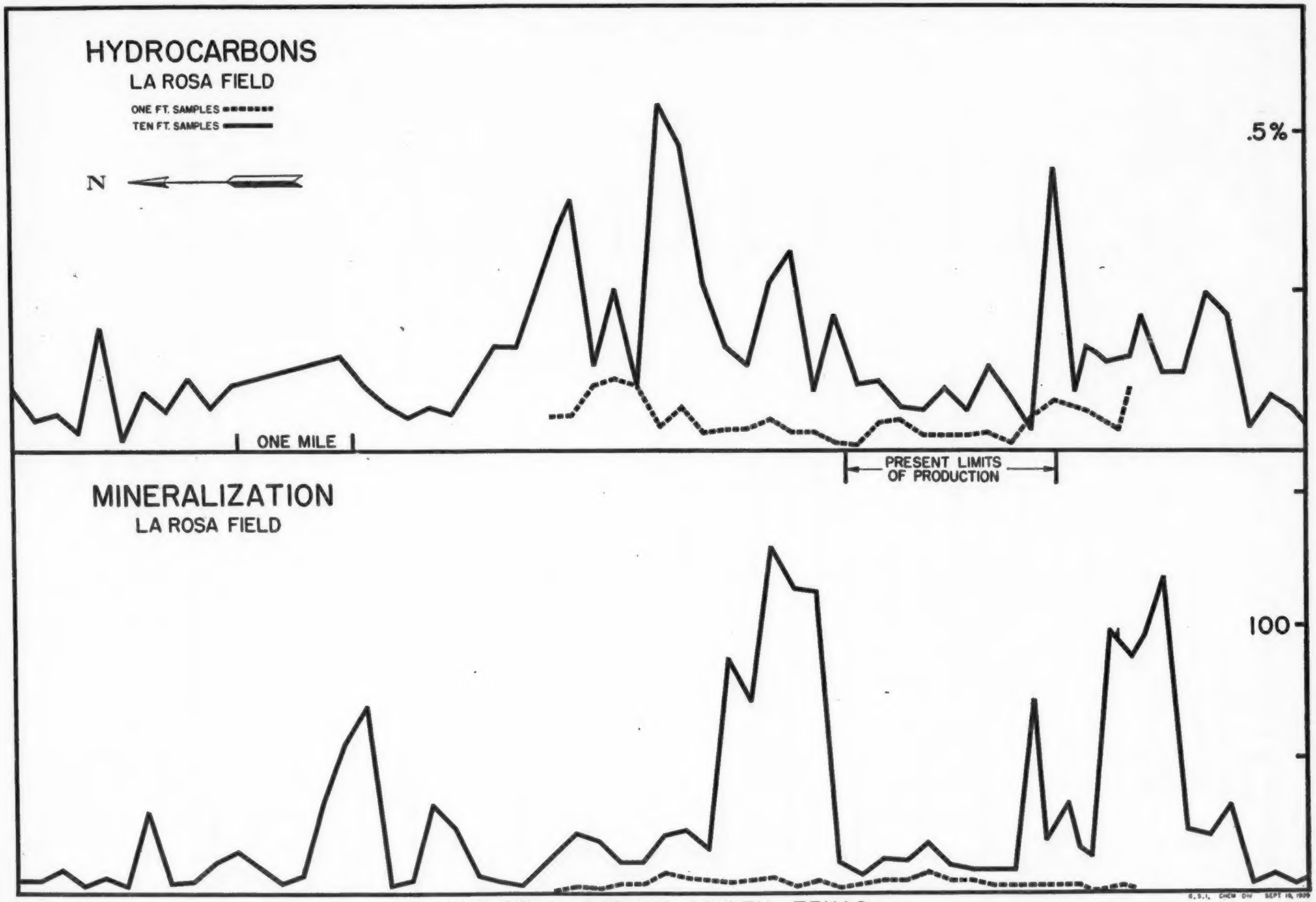

N
A
A
RECONNAISSANCE SURVEY
OF
MINERALIZATION
CEDAR LAKE AREA
GAINES & DAWSON COUNTIES, TEXAS
G.S.I. CHEM. DIV
0 1/2 1 MILE
LEGEND
AVERAGE VALUE ABOVE 20 99
AVERAGE VALUE BELOW 20 4
RATIO 24.7:1

FIG. 3



MONUMENT & HOBBS FIELDS, LEA COUNTY, NEW MEXICO

FIG. 4



LA ROSA FIELD, REFUGIO COUNTY, TEXAS

FIG. 5

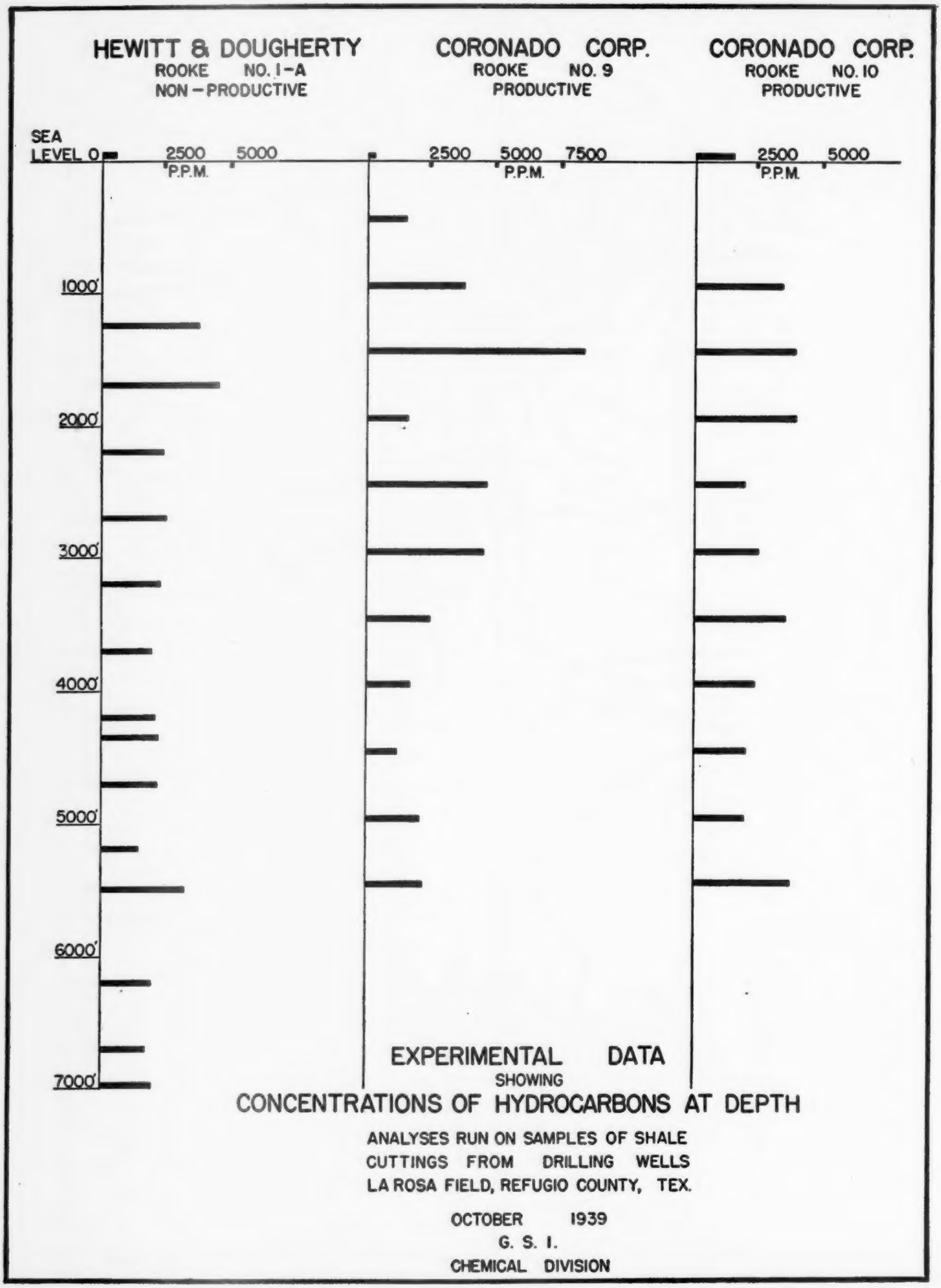

HEWITT & DOUGHERTY
ROOKE NO. 1-A
NON-PRODUCTIVE
CORONADO CORP.
ROOKE NO. 9
PRODUCTIVE
CORONADO CORP.
ROOKE NO. 10
PRODUCTIVE
SEA LEVEL 0
2500
5000
7500
P.P.M.
1000'
2000'
3000'
4000'
5000'
6000'
7000'
EXPERIMENTAL DATA
SHOWING
CONCENTRATIONS OF HYDROCARBONS AT DEPTH
ANALYSES RUN ON SAMPLES OF SHALE
CUTTINGS FROM DRILLING WELLS
LA ROSA FIELD, REFUGIO COUNTY, TEX.
OCTOBER 1939
G. S. I.
CHEMICAL DIVISION

Fig. 6

In Figure 5 are shown sections across the LaRosa field in Refugio County, Texas. The solid lines represent values obtained at a depth of 10 feet and the dashed lines show values obtained at a depth of 1 foot. Obviously contamination due to vegetable matter is not causing trouble in view of the fact that, if this were the case, the 1-foot sample and not the 10-foot sample should show the higher values, whereas the reverse is true.

Cuttings were analyzed at approximately 500-foot depth intervals in three wells in the LaRosa field as shown in Figure 6. Also values are shown for the 10-foot sample. Obviously in view of the fact that the 10-foot sample is the lowest in all cases, what is being measured is not due to some surface cause but is originating from some cause below the surface.

In Figures 7 and 8 hydrocarbon and mineralization maps are shown covering the Coles Levee, Canal, and Ten Section fields in the San Joaquin Valley in California. Samples were obtained immediately after the completion of the discovery well in the Coles Levee area. It is interesting to note in the case of the hydrocarbons that the strongest concentrations occur in the Coles Levee area, whereas the concentrations are weaker in the Canal area which was $1\frac{1}{2}$ years old and the weakest concentrations occur in the Ten Section area which was 3 years old. Although not conclusive, the evidence would indicate that the concentrations disappear after production is started. It is to be expected that the high concentrations would disappear eventually. However, it is very significant that they should disappear in such a short time. Other data have been collected in support of this.

In the case of a simple anticlinal accumulation the ideal type of concentration pattern to be expected is as shown in the left part of Figure 9. In practice a complete "halo" is not always obtained. In the case of a stratigraphic trap a partial "halo" would be expected as shown in the right half of Figure 9. Leakage will occur only from the edge of the accumulation free to expand. Where accumulation is controlled by a fault in many cases the same type of pattern will occur as for the stratigraphic trap. Although a fault plane may at times offer a path of easier leakage, in general it is more apt to be mineralized and more impervious than the surrounding medium.

In view of the fact that there is an appreciable change in normal background values due to what might be termed sampling variation, it becomes necessary to analyze the data to determine what this sampling variation is so that significant values may be chosen for contouring. In Figure 10 are shown three frequency distribution graphs. The abscissa represents values as determined by the analyses. Each

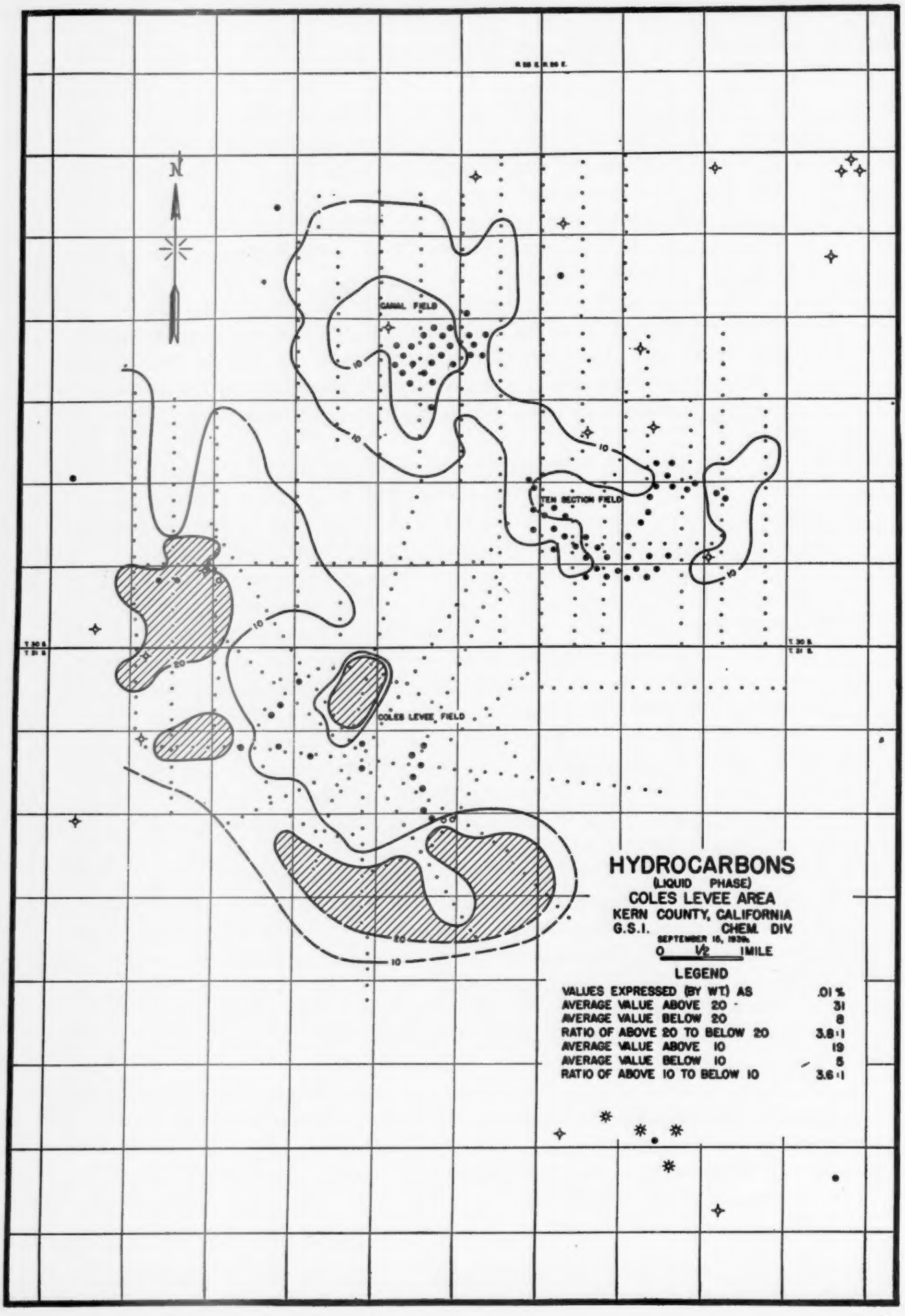

N
CANAL FIELD
TEN SECTION FIELD
COLES LEVEE FIELD
10
20
HYDROCARBONS
(LIQUID PHASE)
COLES LEVEE AREA
KERN COUNTY, CALIFORNIA
G.S.I. CHEM. DIV.
SEPTEMBER 15, 1936
0 1/2 1 MILE
LEGEND
VALUES EXPRESSED (BY WT) AS .01 %
AVERAGE VALUE ABOVE 20 31
AVERAGE VALUE BELOW 20 8
RATIO OF ABOVE 20 TO BELOW 20 3.8:1
AVERAGE VALUE ABOVE 10 19
AVERAGE VALUE BELOW 10 5
RATIO OF ABOVE 10 TO BELOW 10 3.6:1

FIG. 7

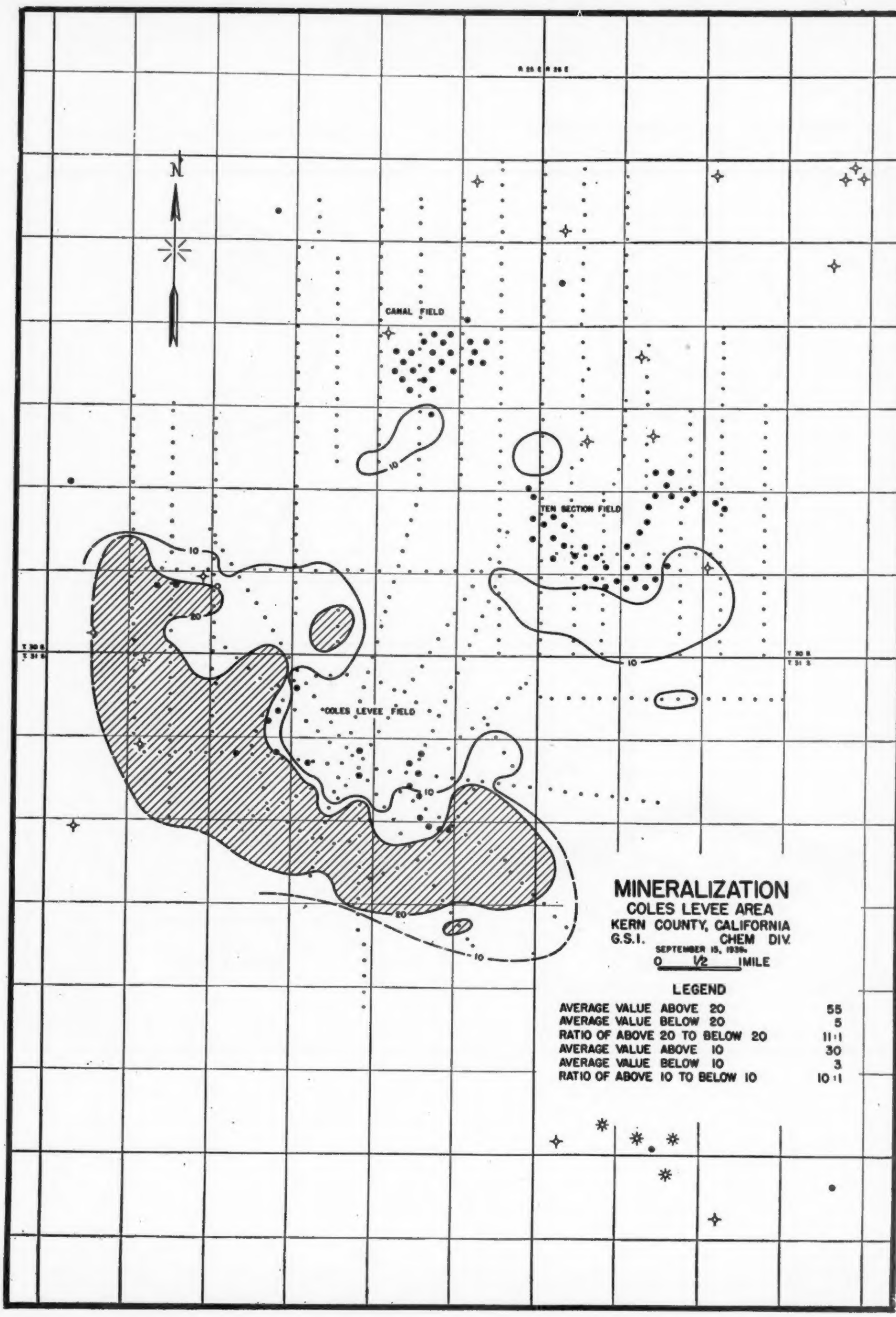

N
CANAL FIELD
TEN SECTION FIELD
COLES LEVEE FIELD
10
20
MINERALIZATION
COLES LEVEE AREA
KERN COUNTY, CALIFORNIA
G.S.I. CHEM DIV.
SEPTEMBER 15,
0 1/2 1 MILE
LEGEND
AVERAGE VALUE ABOVE 20 55
AVERAGE VALUE BELOW 20 5
RATIO OF ABOVE 20 TO BELOW 20 11:1
AVERAGE VALUE ABOVE 10 30
AVERAGE VALUE BELOW 10 3
RATIO OF ABOVE 10 TO BELOW 10 10:1

FIG. 8

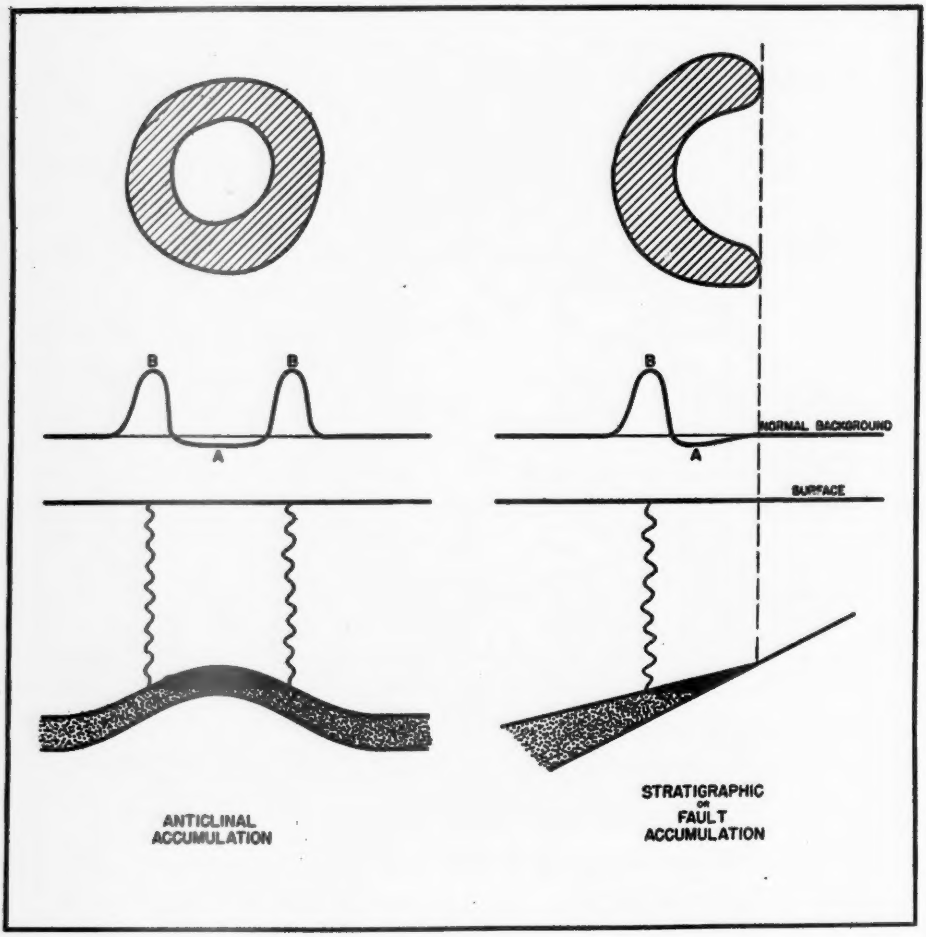
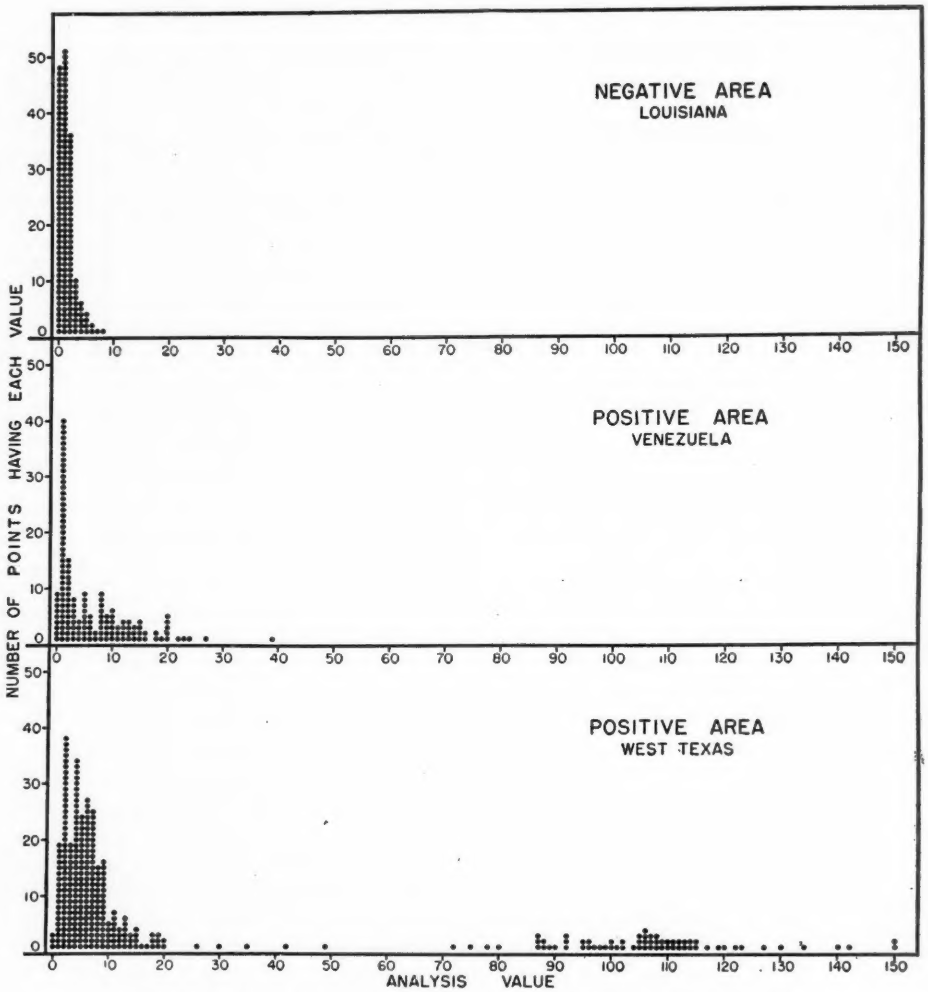

B
B
A
B
NORMAL BACKGROUND
A
SURFACE
ANTICLINAL
ACCUMULATION
STRATIGRAPHIC
OR
FAULT
ACCUMULATION

FIG. 9



FREQUENCY OF OCCURRENCE OF MINERALIZATION VALUES

FIG. 10

dot represents a point in the survey. The first graph, at the top, represents a normal area. The other two represent definitely positive areas.

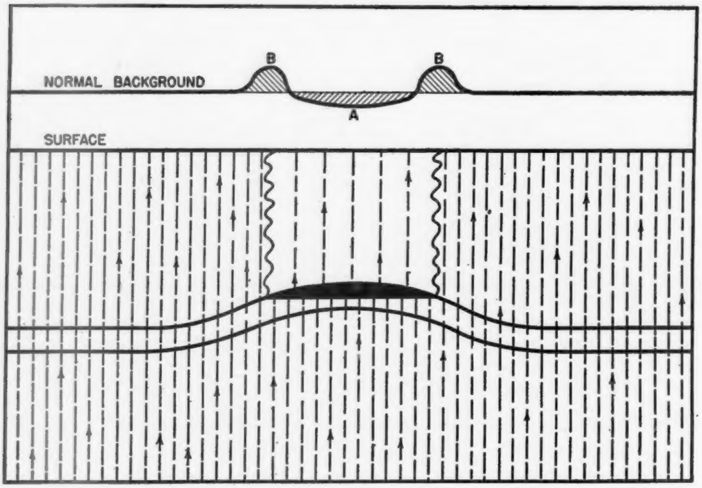


FIG. 11

GENESIS OF OIL AND GAS ACCUMULATIONS

The data of geochemistry have led to some interesting speculations as to the origin and manner of accumulation of oil and gas fields. In view of the fact that concentrations of hydrocarbons as great as 1 per cent have been found near the earth's surface over the edge of an oil field, and bearing in mind that this approaches the order of magnitude of the concentration in an oil field itself, the thought immediately suggests itself that these near-surface concentrations and the concentrations that are commercial oil fields are genetically related. One of the principal differences is the fact that the concentrations near the surface are adsorbed, whereas, the concentrations known as an oil field are free oil. Both result from the leaking gases found to be generally prevalent in the earth, the difference being that conditions were such in the case of the oil field as to permit the formation of free oil and a suitable reservoir was present to hold the oil thus formed.

As oil fields are with few exceptions found in marine sediments, and as the principal difference between marine and non-marine sediments is the presence of salt, it is believed that it is due to the presence of this catalytic agent, namely, salt, that the migrating gases in the

earth are polymerized in the marine sediments to form oil fields. Trask has shown that there is no appreciable difference between marine and non-marine sediments in respect to organic content.

Experimentally it is possible to form solid hydrocarbons or wax by percolating a hydrocarbon gas such as ethylene (found in the earth) through a salt solution. The salt (sodium chloride) water in this case acted as a catalytic agent. Undoubtedly some liquid hydrocarbons were formed but they could not be separated from the relatively large volume of salt water. In fact, there is a commercial process for manufacturing high-grade lubricating oils from unsaturated hydrocarbon gases using aluminum chloride as a catalytic agent. The latter is merely a more effective catalyzer.

After extracting the hydrocarbons from soil samples ethylene gas has been percolated through them for a period of several days. Very appreciable quantities of liquid hydrocarbons were formed on the soil sample by adsorption and polymerization of the gas. Attention is called to the fact that the principal catalyzers used in the petroleum refining industry are special clays.

It has been pointed out that most oils display some optical activity. Evidence indicates that this optical activity is in general very small and is probably due to small amounts of impurities in the oil. There is no evidence to preclude the possibility of the formation of these optically active constituents by polymerization of the hydrocarbon gases. Also such optically active constituents might have been residual in the strata.

Vegetable matter after burial is devolatilized. The products of this process are gases of various kinds, including hydrocarbon gases, and coal. Also, hydrocarbon gases have been found to be present in the basement rocks. So it is but logical to conclude that both buried vegetable matter and the basement rocks are the likely sources of the gases from which our oil and gas fields are derived. It is not intended to attempt to evaluate the relative contributions of these two sources or to exclude other sources, as yet unmeasured, but it is intended to stress the assumption that so far as migration is concerned the gases seem to be the principal participants. One should be careful, however, not to undervalue the potentiality of the great interior of the earth as a source of hydrocarbon gases. Iron containing carbon will under the action of a weak acid evolve appreciable quantities of hydrocarbon gases. A ferromagnesian mixture will give off hydrocarbon gases under the action of water. And finally, carbides in the presence of water will form acetylene which could later form other hydrocarbon gases.[5]

[5] F. W. Clarke, "Data of Geochemistry," *U. S. Geol. Survey Bull.* 770 (1934), p. 740.

The density of hydrocarbon gases in the great interior of the earth would not have to be very great to account for all known oil and gas accumulations in the sedimentaries. Deposits of free iron are found in a number of locations. The most notable are at Ovifak, Disco Island, Greenland. Large masses of iron, in compositions containing about 90 per cent free iron and about 2 per cent of carbon, up to 20 tons by weight, are found embedded in the basalt.[6]

The possible contribution of animal matter is omitted from this discussion as there is no evidence to indicate that animal matter survives in any great quantity, whereas there is ample evidence in the case of vegetable matter.

The gases from the vegetable matter and the basement rocks are of course organic. However, if in either case one goes one step further in the direction of origin, in both cases the origins are found to be inorganic. In view of this can it be said that there has ever been an entirely organic theory of the origin of oil and gas?

As there is ample evidence that hydrocarbon gases are leaking through the earth and that some of these gases, in all probability the unsaturated ones, will polymerize to form liquid hydrocarbons, it is reasonable to assume that oil accumulations are formed in this manner. In Figure 11 the density of the vertical dashed lines represents the density of vertically migrating gases. Of these gases the very stable methane is the principal constituent. If these gases are collecting and polymerizing to form the accumulation, it necessarily follows that the concentrations over the accumulation must be less than normal. This is indicated by the wider spacing of the dashed lines. It is possible, though, to have a higher concentration pattern over the edges of the accumulation which will be considered later.

If the permeability of the cap rock is sufficiently low the stable methane which is dominant in the migrating hydrocarbon gases will collect in a structural trap, along with much smaller quantities of the more unstable gases such as ethylene. However, in view of the predominance of methane a gas field will form. There may of course be other gases present such as nitrogen or carbon dioxide which may also be trapped.

If the permeability of the cap rock is greater than here assumed, the lighter and smaller molecular weight methane will escape faster than the much more reactive ethylene for instance. Consequently, the latter will have an opportunity to polymerize to form an oil field. The heavier hydrocarbons formed will tend to clog the cap rock, thus re-

[6] *Ibid.*, p. 332.

ducing further escape over the accumulation. However, as the accumulation grows its edges will extend beyond the clogged area (assuming a time lag for the clogging effect) and so there will result an increased leakage at the edges of the accumulation. It is interesting to note that this type of leakage is a necessary consequence of the assumptions made and that it is amply verified by experimental surveys over known oil fields.

If the permeability of the cap rock is still greater none of the gases will be slowed up sufficiently to permit the polymerization processes to operate and neither an oil nor a gas accumulation will result.

Experimental surveys over known fields indicate that the leakage is essentially vertical (in areas of low or medium relief). It is believed that this is due to the fact that the permeability of shales is due to microscopic fissures which are essentially vertical.

As a result of the forces of deformation or over-burden the permeability of the cap rock will be decreased and as a result a relatively larger proportion of the unreactive methane will be trapped, resulting in a more volatile accumulation. As the deformation becomes greater only gas accumulations will occur. However, if the deformation becomes too great, the permeability of the cap rock will increase because, as its elastic limit is reached, fissures will be developed. This explains the relations existing between the carbon ratio of coals and the occurrence of oil and gas as set forth by the carbon-ratio theory of David White.

The presence of hydrocarbons in a rock does not necessarily mean, in the absence of other evidence, that it is a source rock. It might instead be a reservoir rock. In view of the evidence for the prevalence of hydrocarbon gases leaking through the earth, and especially in view of the fact that the great interior of the earth may be a source of such hydrocarbons (and it is not unreasonable to credit it with great potentiality as a storehouse of energy and materials), perhaps more attention should be paid to "cap rocks" over porous reservoirs than to "source rocks." The presence of oil or gas accumulations may be more dependent on the physical and perhaps the chemical characteristics of such cap rocks than on any other factor.

If the character of the cap rock is the important factor it follows that, other things being equal, the chances of the occurrence of an oil or gas accumulation for a given thickness of sediments drilled will be proportioned to the number of sand-shale contacts. This must be the case as the chances of encountering a cap rock of the right characteristics will be proportional of course to the total number of contacts

encountered. This is substantiated by the fact that Tertiary sediments which have a large number of stratigraphic changes are most prolific.

It is believed that the concentrations of hydrocarbons in oil shales are genetically related to the concentrations occurring on soil samples. The principal difference noted between an oil shale and an average soil sample is the fact that the particle size is much smaller in the case of the oil shale. This, of course, means that adsorption and polymerization abilities of the oil shale are very great and explain the large concentrations of adsorbed hydrocarbons found in oil shales. It is possible that some of the hydrocarbon gases adsorbed by the shale may have originated in organic matter indigenous to the shale.

It is believed that the so-called "tar sands," which are really heavy oil sands, such as the Athabaska oil sand in Alberta Province in Canada, are not the same in point of genesis as our commercial oil fields, especially in view of the fact that the accumulations occur in non-marine sediments and are not associated with structure. It seems reasonable to assume that the accumulation in these "tar sands" may result from the transformation or organic matter in place into the heavy oil in the manner set forth by E. Berl.[7] Of course, there may be minor contributions made by the migrating gases from other sources going into solution in the heavy oil. In the case of the oil field which it is assumed is formed essentially by the polymerization of migrating gases, there may be a minor contribution from organic matter in place in the manner described by Berl. This could easily account for the optical activity of the oil.

MINERALIZATION

The very high mineral concentrations occurring in conjunction with high hydrocarbon concentrations over the edges of some oil fields impresses one with the great transporting power of the gases that are migrating through the earth.

An interesting example of a mineral concentration connected with leaking gases occurred in Angelina County in Texas. A saline called the Graham saline led to the drilling of a well about 1924. It is interesting that this saline was used as a source of commercial salt during the Civil War. The well was drilled to a depth of approximately 3,000 feet. It produced salt water and gas and was allowed to flow. In 1926 the saline was still in existence. In 1931 the saline had largely disap-

[7] E. Berl, "The Rôle of Carbohydrates in the Formation of Oil and Bituminous Coals." Manuscript read before the American Association of Petroleum Geologists at Chicago, April 11, 1940.

peared and was covered with growth. Apparently, as a result of releasing the gas pressure, the minerals in the saline were not replenished from below and consequently the salt in the saline was gradually leached away by the elements, resulting in its demise.[8]

It is reasonable to believe that large quantities of subsurface waters and the minerals dissolved in them have during the course of time been transported to the surface. The subsurface waters in the Rocky Mountain area are meteoric in character. Those in the Appalachian area are highly concentrated and in some instances no water is present and oil is found in synclines. Fossil remains indicate that originally in both areas the subsurface waters were similar to present sea water. The principal difference in the two areas is the fact that the subsurface sands in the Rocky Mountain area are quite permeable, whereas the subsurface sands in the Appalachian area are relatively impermeable. It is but logical to conclude that in the Rocky Mountain area, due to the high sand permeability, the connate waters were replaced by meteoric waters entering at the outcrops as fast as the connate waters were removed by the vertically migrating gases. In the Appalachian area, due to the relatively low permeability of the subsurface sands, the meteoric waters did not enter the sands as fast as the connate waters were removed. As the minerals, being heavier, were not removed as fast as the waters, there resulted waters of high mineral concentrations.

It is quite likely that the formation of caliche is due to the upward transportation of carbonate waters to the surface. The water will evaporate, leaving the carbonate and perhaps other minerals in minor amounts at the surface.

It should be kept in mind that solubility is a relative term. Minerals generally regarded as insoluble may be transported in the aforedescribed manner. For instance, gold in colloidal form may be so transported and deposited. In fact, there are instances where it has apparently been deposited in such fashion.[9] Also, it seems likely that the mercury deposits at Terlingua, Texas, have a similar genesis.[10] Furthermore, instances of secondary mineralization, such as anhydrite nodules in limestone, may be accounted for by the transporting power of the upward-moving gases.

In conclusion it should be kept in mind that the method of geochemical exploration is not predicated on the theoretical conceptions

[8] Lewis W. MacNaughton, personal communication.

[9] S. F. Emmons, personal communication.

[10] Ben C. Belt, personal communication.

here presented. Rather, the reverse is true in that the theory is derived from the data of geochemistry.

BIBLIOGRAPHY

1933

LAUBMEYER, G., "A New Geophysical Prospecting Method, especially for Deposits of Hydrocarbons," *Petroleum*, Vol. 29, No. 18, pp. 1–4.

SOKOLOV, V. A., *Methods of Exploration for Natural Gas*. Publisher not known.

SOKOLOV, V., "Gas Surveying," *Azerbaidzhanskoe Neftyanoe Khozyaistvo*, No. 9, pp. 73–75. English translation in *Foreign Petroleum Technology*, Vol. 6, Issue 8 (August, 1938).

SOKOLOV, V. A., "New Method of Prospecting Oil and Gas-Bearing Regions." Read at the Oil Geological Prospecting Conference in Moscow in January, 1933. *Information Bulletin of the "NGRI,"* No. 1. Also *Azarbaydzhanskoye Neftyanoye Khozyaistvo*, No. 9.

1934

ANTONOV, P. L., "The Theory of Gas Surveying," *Neftyanoe Khozyaistvo*, No. 5, pp. 19–23. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 7 and 8 (July and August, 1939).

SOKOLOV, V. A., and YUR'EV, YU. K., "Gas Survey of the Mel'nikovo Gas Deposit," *ibid.*, Vol. 26, No. 1, pp. 20–22. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 9 and 10 (September and October, 1939).

VIKTOROV, B. N., "Attempted Interpretation of Gas Surveying Data," *ibid.*, No. 9, pp. 13–16. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 9 and 10 (September and October, 1939).

1935

SOKOLOV, V. A., "Results of the Experimental Work on Gas Surveying," *ibid.*, No. 5, pp. 28–34. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 9 and 10 (September and October, 1939).

ANTONOV, P. L., "The Problem of Outlining Petroleum Deposits by the Findings of Gas Prospecting," *ibid.*, No. 10, pp. 33–35. English translation in *Foreign Petroleum Technology*, Vol. 5, Issue 4 (April, 1937).

MOGILEVSKII, G., "The Method of Gas Surveying Should Be Used Extensively," *ibid.*, No. 5, pp. 35–38. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 9 and 10 (September and October, 1939).

1936

SOKOLOV, V. A., edited by GUBKIN, I. M., *Gas Surveying*. Russian edition published by ONTI NKTP, SSSR, 1936, Glavnaya Redaktsiya Gorno-Toplivnoi Literatury, Moscow-Leningrad. English translation by A. A. Boehtlingk, Berkeley, California.

GABRIELYAN, S. M., and TILYUPO, I. A., "Micro-Analysis of Soil Air in Gas Surveying," *Grozmenskii Neftyanik*, 6, No. 9, pp. 29–32. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 11 and 12 (November and December, 1939).

ANTONOV, P. L., "One of the Modifications of the Gas Surveying Method," *Neftyanoe Khozyaistvo*, No. 8, pp. 27–29. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 11 and 12 (November and December, 1939).

———, "The Evaluation of Producing Layers by the Gas Surveying Method," *ibid.*, No. 8, pp. 29–31. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 11 and 12, (November and December, 1939).

SOKOLOV, V. A., "Interpretation of Gas Surveying Data." English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 11 and 12 (November and December, 1939).

1937

SOKOLOV, V. A., "The Question concerning the Interpretation of Gas Analysis," *Neftyanoye Khozyaistvo*, No. 12.

BEZDROBNYI, D. A., "Some Disadvantages of Gas Surveys when Prospecting for Petroleum Deposits," *Grozenskii Neftyanik*, 7, No. 3, pp. 31–36. English translation in *Foreign Petroleum Technology*, Vol. 6, Issue 8 (August, 1938).

SOKOLOV, V. A., and KRUGLYAKOVA, P. P., "Micro-Analysis in Gas Surveying," *Gyulleten Neftyanoi Geofiziki*, Vol. IV, pp. 72–77. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 1 and 2 (January and February, 1939).

1938

TUCKER, MITCHELL, "Soil Analysis Surveys Being Made as an Aid in Geophysical Studies," *Oil and Gas Jour.* (June 23), p. 20.

1939

ROSAIRE, E. E., *The Handbook of Geochemical Prospecting* (First Edition, 1939). Printed for private circulation.

TUCKER, MITCHELL, "Soil Analysis Evaluated by Means of Test Holes," *Oil and Gas Jour.* (June 15), p. 37.

HOFFMAN, MALVIN G., "An Advance in Exploration by Soil Analysis," *ibid.* (March 16), p. 23.

ARISTARKHOVA, M. V., "Apparatus for the Determination of Small Amounts of Hydrocarbons in Air," *Azerbaidzhanskoe Heftyanoe Khozyaistvo*, No. 7, pp. 15–18. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 7 and 8 (July and August, 1939).

YUROVSKII, YU. M., "Brief Review of Up-to-Date Gas Surveying Methods," *Razvedka Nedr*, 9, No. 3, pp. 35–40. English translation in *Foreign Petroleum Technology*, Vol. 7, Issues 5 and 6 (May and June, 1939).

ROSAIRE, E. E., *Hydrogen-Hydrocarbon Well Logging*. Supplement No. 1 to the *Handbook of Geochemical Prospecting*. Discussion concerning various papers appearing in *Geophysics* relative to soil analysis in regard to petroleum prospecting. *Geophysics*, Vol. 4, No. 4, pp. 300–04.

HORVITZ, LEO, "On Geochemical Prospecting," *Geophysics*, Vol. 4, No. 3, pp. 210–25.

ANON., *Method of Sampling for Soil Surveys*. Folder published by Geophysical Service Inc., in the fall of 1939.

MCDERMOTT, EUGENE, "Concentrations of Hydrocarbons in the Earth," *Geophysics*, Vol. 4, No. 3 (July). Also printed for private circulation, 1939.

ANON., *Soil Surveys*. Booklet published by Geophysical Service Inc., in May, 1939. Out of print.

ANON., "Progress in Soil Survey Methods," *Oil and Gas Jour.* (September 14), p. 53.

STEINMANN, KURT W., "Use of the Transient and Soil Analysis Methods in the Search for Oil," *ibid.* (July 27), p. 83.

STORMONT, D. H., "Gulf Coast Field Is Opened on Soil Survey Information," *ibid.* (July 20), p. 29.

1940

HOOVER, HERBERT, JR., and WASHBORN, HAROLD, "A Preliminary Report of the Application of the Mass Spectrometer to Problems in the Petroleum Industry." Read before the Petroleum Division, A.I.M.M.E., at the 152nd meeting, New York, February 13.

LEBARON, MILTON, "Determining the Presence of Oil," *Oil and Gas Jour.* (January 11), p. 43.

SIMONS, HARRY F., "Scope of Soil Analysis Increased During Year," *ibid.* (February 29), p. 54.

PIKE, R. W., et al., "Source Rocks of Petroleum—A Symposium of Opinion" (Discussion of McDermott's "Concentrations of Hydrocarbons in the Earth," published in *Geophysics*, Vol. 4, No. 3, July, 1939), *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 3 (March), pp. 496–503.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 5 (MAY, 1940), PP. 882-887

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available, for loan, to members and associates.

GRÖNLAND 1939, BY MANY AUTHORS

REVIEW BY ROBERT BALK[1]
Mount Holyoke, Massachusetts

"Grönland 1939." *Mitteilungen der Naturforschenden Gesellschaft Schaffhausen* (Switzerland, 1939), Vol. 16. 231 pp., numerous plates and figures.

The geological investigation of Greenland has made rapid strides in recent years, thanks to the well financed and skillfully organized expeditions of Danish and other European scientists. Although two summaries of the geology of Greenland have been published within the past few years, one by Lauge Koch, the other by Curt Teichert, the present volume is a welcome addition to the literature as it gives much new information, especially on eastern Greenland. The volume is a series of 20 papers delivered at a joint meeting of Swiss, Scandinavian, German, and Dutch scientists, organized by C. E. Wegmann and H. Bütler for the Society of Natural History at Schaffhausen, Switzerland.

In his introduction, C. E. Wegmann (pp. 29–46) stresses the aim of the meeting: to formulate and discuss jointly the divers geological problems of Greenland. These range from the mechanics of mountain-building and migmatitization to stratigraphic, paleontologic, and volcanologic questions and include such difficult fields as the reconstruction of the late Paleozoic paleogeography of east Greenland, the relation of the mineral composition of Recent sands to the distribution of rocks below the inland ice, the Tertiary history of Davis Strait, the anatomy of the lemming, aërial photography, and others. Only a few of the papers can be summarized in this review.

The east Greenland mountain range consists of an ancient basement complex, overlain by approximately 24,000 feet of late pre-Cambrian and early Paleozoic sediments. All of these rocks have been deformed and in part injected or migmatized before the deposition of thick Devonian sediments in "red clastics" facies. The structural geology of this area is outlined by C. E. Wegmann (pp. 82–104). The Devonian system is discussed by H. Bütler (pp. 105–131) and A. von Moos and A. Müller (pp. 138–145). Erik Stensiö (pp. 132–137) reports progress in the investigation of the remarkable fish remains from the late Devonian shales. About 20,000 specimens are available for study, and 30 species of 18 genera and 5 larger groups have so far been identified. Most abundant of all species is *Remigolepis*, a late member of the Antiarchi group. There are four genera of Arthrodira, also Crossopterygii, Dipnoi, and an unnamed new group, of particular paleontologic interest for the skull osteology suggests that this group, like the Crossopterygii, tended to develop features resembling primitive tetrapoda.

A. Rittmann (pp. 146–151) discusses the volcanic rocks of the eastern mountain range. The Devonian sequence consists of oldest basalt sills and flows, followed by tholeiites and lamprophyres, aplitic granites, and flows and

[1] Manuscript received, March 26, 1940.

tuffs of alkaline rhyolites. Another group of rhyolites is of Carboniferous age. In contrast, the Cretaceous-Tertiary extrusives, largely basalt, are of Atlantic types.

The stratigraphy of the post-Carboniferous strata of east Greenland is summarized by A. Vischer (pp. 152–160), W. Maync (pp. 161–164), and H. Stauber (pp. 167–175). The rocks lie on the oceanward side of the mountain range, and the succession of strata is greatly complicated, but their study very interesting, on account of the disturbing effect of long-continued normal faulting, resulting in rapid changes in thickness in all formations, and various combinations of overlaps, offlaps, unconformities, and disconformities. Thus the stratigraphic problems greatly resemble those of certain Rocky Mountain areas of Colorado, and particularly those of the Cretaceous and Tertiary rocks of California.

The crystalline rocks of south Greenland are discussed by C. E. Wegmann (pp. 188–212), and a paper by H. E. Kranck (pp. 213–216) deals with similarities in the pre-Cambrian rocks of Greenland and Labrador. Two short papers by C. H. Edelman (pp. 217–220) and H. Hübscher (p. 221) on problems of sand analyses, and an article by M. Zeller (pp. 222–227) on aërial photography conclude the volume.

Armin Öpik (pp. 47–69) examines the question whether the paleontology of the Cambro-Ordovician terranes of northwest Europe and Greenland requires displacements of major dimensions of parts of the north European continent. He concludes that, although continental drift would naturally simplify the problem by the reduction of some distances, it can not be said that the paleontologic evidence is compelling. Most of the problems admit of more than one solution. He adds a large list of references.

Lauge Koch (pp. 70–81) outlines the history of exploration of Greenland from 1822 to date. Among the scientific men engaged in the work on this continent he distinguishes three groups: those of the first "travel, observe, measure, draw, and collect." The second group studies and describes the collected material in the laboratory. Those of the third group "read the published papers of the first two [groups], weigh carefully every word against every other, and about this they write continuous series of additional publications."

THIS FASCINATING OIL BUSINESS, BY MAX W. BALL

REVIEW BY W. V. HOWARD[1]
Tulsa, Oklahoma

This Fascinating Oil Business, by Max W. Ball. 444 pages. Illustrated. The Bobbs-Merrill Company, Indianapolis (1940). Price, $2.50.

When the cute little number looks up from her glass and says, "So, you're a geologist. I think it's simply wonderful the way you know all about what lies under the earth!" you can do one of three things. You may modestly disclaim any special ability (which is poor strategy), you may explain exactly how wonderful you are (which is poorer strategy and a waste of valuable time), or you can give her a copy of Max Ball's book. Then after a week you can borrow it back and read it yourself with great interest and greater profit, for that is exactly the kind of book it is.

[1] Manuscript received, April 2, 1940.

This Fascinating Oil Business fills a need that is almost as old as the oil business itself. It describes the oil game from start to finish in the most interesting way possible. It will demonstrate to the layman why it is impossible for anyone in the oil business to refrain from talking shop for very long and also why no person who has ever got into the oil business has left it willingly. The author discusses all phases of the oil industry from exploration to the filling station and finds space to liven his discussion with humor most effectively.

He reviews the distribution of oil throughout the world and gives the high spots regarding each country's production. Finally, he presents an illuminating and timely chapter on "Oil and the War."

Lest it be considered that such a book will be sketchy, it is only necessary to recapitulate the section headings in the 20-page chapter on "Producing the Oil—the Mechanics of It." These are: "Pressures; The Well Connections; Oil and Gas Separators; Recovering the Casinghead Gasoline; Wet Gas Wells; The Field Tanks; B S & W; Treating Cut Oil; Tubing the Well; All Wells to the Pumps; Gas Lift and Air Lift; On the Pump; Power and 'Powers'; Bailing and Swabbing; Cleaning and Repairing; Stripper Wells; The Life of a Field; Pressure Maintenance; Secondary Recovery Methods; Repressuring, Gas Drive; Air Drive; Water Drive; Underground Drainage; Mining Oil Sand; The Cost of Producing Oil." Each of these topics is discussed in a few paragraphs that are masterpieces of succinctness, touched with a humor that is almost as fascinating as the author's topic.

The chapter on "New Worlds to Conquer" gives the reader an insight into the research that is being carried on by the industry and tells about "Your Day," a section which should be quoted in its entirety. At the end of the perfect petroliferous day,

> when the guests have gone and your wife is preparing for the night with cold cream with an oil-product base, you remember the cold you thought was coming on. You take a hot bath and follow with an alcohol rub using bathing alcohol made from oil. Then, for safety's sake, you take a swig of liquid petrolatum. And so to bed, to dream of a time when the oil business may, if you wish, supply you with every requirement of food, clothing, shelter, transportation, livelihood and recreation.

When that dream comes true, somebody may have written a more interesting book about the oil business, but he will have had a mighty tough job on his hands.

This Fascinating Oil Business is a definite "must."

RECENT PUBLICATIONS

BRAZIL

*"Reasons for Locating an Oil Well at Recôncavo, Baia," by Glycon de Paiva and Irnack Carvalko do Amaral. *Brasilian Bur. Mines, Avulso 40* (Rio de Janeiro, 1939). 23 pp., 6 pls. In Portuguese.

*"Deep Drilling Prospects," by Glycon de Paiva and Irnack Carvalko do Amaral. *Ibid., Bol. 36.* 60 pp.

EUROPE

*"Late Prospecting Brightens Outlook for Paleozoic Oil in Western Europe," by W. A. J. M. van Waterschoot van der Gracht. *Oil Weekly* (Houston), Vol. 97, No. 2 (March 18, 1940), pp. 126–29; 3 photographs.

GENERAL

**Annual Report for 1938–1939. Natl. Research Council, Div. Geol. and Geography* (2101 Constitution Avenue, Washington, D. C., December, 1939). Approx. 220 multigraphed pp. Contains list of members of the Division and its committees, minutes of annual meeting, chairman's report (Chester R. Longwell) and reports from committee chairmen. Free, except for 15¢ postage.

*"Outline of Direct and Indirect Means of Locating Oil," by W. V. Howard. *Oil and Gas Jour.* (Tulsa), Vol. 38, No. 45 (March 21, 1940), pp. 27–28.

*"Many Sciences Called into Use in Oil Exploration," by W. V. Howard. *Oil and Gas Jour.* (Tulsa). Vol. 38, No. 44 (March 14, 1940), pp. 23, 98–99.

*"Early Man in America: Index to Localities and Selected Bioliography," by E. H. Sellards. *Bull. Geol. Soc. America* (New York), Vol. 51, No. 3 (March 1, 1940), pp. 373–432; 4 figs., 1 pl.

*"Ecology of Modern Marine Organisms with Reference to Paleogeography," by Thomas Wayland Vaughan. *Ibid.*, pp. 433–68; 8 figs.

*"Tertiary Forests and Continental History," by Ralph W. Chaney. *Ibid.*, pp. 469–88; 2 pls., 3 figs.

*"Permian Ammonoids of the Guadalupe Mountain Region and Adjacent Areas," by A. K. Miller and W. M. Furnish. *Geol. Soc. America Spec. Paper 26* (March 15, 1940). 242 pp., 44 pls., 59 figs., 6 tables.

GEORGIA

*"Oil Search in Georgia Covers Wide Front," by Arthur C. Munyan. *Oil and Gas Jour.*, Vol. 38, No. 44 (March 14, 1940), pp. 24–26; 99–100; 3 photographs, 2 maps, 1 stratigraphic column.

GERMANY

*"Results of Deep Drilling in the Petroleum Region of Tegernsee in Upper Bavaria," by Jos. Knauer. *Oel und Kohle mit Petroleum* (Berlin), Vol. 36, No. 7 (February 15, 1940), pp. 63–66; 7 figs. In German.

ILLINOIS

"Geology of the Chicago Region—Part I, General," by J Harlen Bretz. *Illinois State Geol. Survey Div. Bull. 65* (Urbana, 1940). 118 pp., 7 pls., 91 figs., geologic map in color. Prepared for schools and laymen. Price, $0.50.

LOUISIANA

*"Ground-Water Resources of Rapides Parish, Louisiana," by John C. Maher. *Louisiana Geol. Survey, Bull. 17* (New Orleans, January 1940). 100 pp., 10 pls., 12 figs.

MISSISSIPPI

*"Geology and Economic Significance of Mississippi Oil Development," by Joseph A. Kornfeld. *World Petroleum* (New York), Vol. 11, No. 3 (March 1940), pp. 38–52; 18 illus.

*"Sulphur Springs Creek Fault, Winston County, Mississippi." *Mississippi State Geol. Survey Press Memo.* (April 2, 1940). 1 mim. page.

NEVADA

*"Geomorphology of the Ruby-East Humboldt Range, Nevada," by Robert A. Sharp. *Bull. Geol. Soc. America* (New York), Vol. 51, No. 3 (March 1, 1940). pp. 337–72; 4 pls., 12 figs.

SOUTH DAKOTA

*"A Magnetic Survey of South-Central South Dakota," by W. H. Jordan and E. P. Rothrock. *South Dakota Geol. Survey Rept. Investig. 33* (Vermillion, February, 1940). 19 multigraphed pp., 5 figs., 1 pl., 1 folded map.

TURKEY

*"Brief Review of the Tectonic Structure of Anatolien," by Wilhelm Salomon-Calvi. *Maden Tetkik Arama Enstitit. Mecmuasi*, Sene 5, Sayi 1–18 (Ankara, 1940), pp. 35–74; 2 figs. In German.

*"Tectonic Features of Eastern Anatolien and Adjacent Regions," by P. Arni. *Turkish Stratigraphic Research Institute*, Ser. B, Paper 4 (Ankara, 1939). 90 pp., 7 figs., 5 pls. In Turkish and in German.

WASHINGTON

*"Olympic Peninsula Petroleum Possibilities," by W. C. Lehman. *California Oil World* (Los Angeles), Vol. 33, No. 5 (March, 1940, first issue), pp. 5–12; 10 photographs.

WEST INDIES

*"Hispaniola—A New Oil Province," by F. B. Plummer. *Oil Weekly* (Houston), Vol. 97, No. 2 (March 18, 1940), pp. 193–96; 1 map, 2 photographs.

*"Fifty Rigs Kept Busy as Cuba Attains Peak," *anon. Ibid.*, pp. 199–220; 1 photograph.

WYOMING

"Geological Map of East Lance Creek Oil and Gas Field, Niobrara County, Wyoming," by W. B. Kramer, C. E. Dobbin, and Robert McMillan. U. S. Geol. Survey, Washington, D. C.; U. S. Customhouse, Denver, Colorado; Federal Building, Casper, Wyoming. Free. *U. S. Geol. Survey Press Release P. N. 94425* (March 19, 1940). 2 pp.

"Geologic Map and Section of the Red Springs Anticline, Hot Springs County, Wyoming," by C. E. Dobbin and W. B. Kramer. U. S. Geol. Survey, Washington, D. C.; U. S. Customhouse, Denver, Colorado; Federal Building, Thermopolis, Wyoming. *Ibid., P. N. 94424* (March 19, 1940). 1 p.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Paleontology* (Tulsa, Okla.), Vol. 14, No. 2 (March, 1940).

"A New Cystoid from the Ordovician of Oklahoma," by E. B. Branson and Raymond E. Peck.

"Foraminifera from the Grayson Formation of Northern Texas," by Helen Tappan.

"Radiolarian Fauna of the Caballos Formation, Marathon Basin, Texas," by Esther Aberdeen.

"*Helicoprion* in the Permian of Western Australia," by Curt Teichert.

"The Gastropod Genus *Euphemites* in the Pennsylvanian of Texas," by Ralph H. King.

**Journal of Sedimentary Petrology* (Tulsa, Oklahoma), Vol. 10, No. 1 (April, 1940).

"The Tenth Volume," by W. H. Twenhofel.

"Mineral Study of Santa Rosa Sandstone in Guadalupe County, New Mexico," by Raymond Sidwell and Donald Gibson.

"Notes on the Mineral Assemblage of the 'White Silt' Terraces in the Okanagan Valley, British Columbia," by Charles Meyer and Keith Yenne.

"Authigenic Albite from the Lowville Limestone at Bellefonte, Pennsylvania," by Arthur P. Honess and Charles D. Jeffries.

"Sediments of Buzzards Bay, Massachusetts," by J. L. Hough.

"Sedimentary Studies of the Wapsipinicon Formation in Iowa," by Ellis H. Scobey.

* *Journal of Paleontology* (Tulsa, Okla.), Vol. 14, No. 3 (May, 1940).

"Molluska of the Chickasawhay Marl," by Wendell C. Mansfield.

"Eocene Brachiopods from the Salt Mountain Limestone of Alabama," by Lyman D. Toulmin.

"Lower Trenton Decorah Fauna," by G. Marshall Kay.

"*Prismatophyllum* in the Cedar Valley Beds of Iowa," by Merrill A. Stainbrook.

BARIUM IN APPALACHIAN SALT BRINES

E. T. HECK

(Addendum)

The article, "Barium in Appalachian Salt Brines," by E. T. Heck, assistant geologist of the West Virginia Geological Survey, Morgantown, West Virginia, published in the March *Bulletin*, pages 486–93, was presented, prior to publication, before the meeting of the American Association for the Advancement of Science, in Columbus, Ohio, December 27, 1939, and before the Appalachian Geological Society, at Charleston, West Virginia, January 8, 1940.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 5 (MAY, 1940), PP. 888-943, 5 FIGS

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

George Harold Anderson, Dallas, Tex.
Ian Campbell, John P. Buwalda, Hampton Smith
Kenneth LeMay Chasey, Mattoon, Ill.
H. H. Arnold, Jr., B. Maxwell Miller, Verner Jones
Joseph William Lea, Dallas, Tex.
F. H. Lahee, James A. Waters, R. E. Rettger
Wesley R. Lund, Great Bend, Kan.
L. C. Morgan, John W. Inkster, S. W. Holmes
Harluf C. Petersen, New Orleans, La.
Cyril K. Moresi, R. A. Steinmayer, Alexander Deussen
Robert Hillyer Ray, Houston, Tex.
A. L. Selig, Dave P. Carlton, Henry C. Cortes
James Udell Teague, W. Columbia, Tex.
Paul Weaver, Albert G. Wolf, William B. Heroy

FOR ASSOCIATE MEMBERSHIP

George Elmer Dunlap, Dallas, Tex.
A. N. Murray, A. F. Truex, S. H. Woods
Lynn Delbert Ervin, Glenwood Springs, Colo.
Dart Wantland, W. A. Waldschmidt, F. M. Van Tuyl
Lester Newhouse, New York, N. Y.
W. A. Waldschmidt, J. Harlan Johnson, F. M. Van Tuyl
Wilbur Frank Rogers, Scottsbluff, Neb.
E. F. Schramm, E. C. Reed, A. L. Lugn

FOR TRANSFER TO ACTIVE MEMBERSHIP

Charles Hatton Coldwell, San Antonio, Tex.
F. E. Heath, James A. Waters, F. H. Lahee
Edward Charles Cram, Puerto Wilches, Colombia, S.A.
Ben B. Cox, C. S. Corbett, A. C. Tester
Lewis Owen Kelsey, Dallas, Tex.
T. K. Knox, Joseph M. Wilson, W. W. Clawson
Paul L. Lyons, Tulsa, Okla.
E. O. Markham, L. Murray Neumann, Stuart Sherar
Donald J. MacNeil, Wichita Falls, Tex.
F. A. Bush, R. B. Rutledge, Sherwood Buckstaff
George T. McIntyre, Oklahoma City, Okla.
H. T. Brown, T. C. Hiestand, Murray J. Wells
Victor William Rogers, Midland, Tex.
Roy R. Morse, Kenneth S. Ferguson, Julian Q. Myers
Edward W. Scott, Bakersfield, Calif.
Desaix B. Myers, E. K. Soper, A. A. Curtice
Raymond D. Sloan, Tulsa, Okla.
D. C. Nufer, Phil K. Cochran, M. A. Dresser

TWENTY-FIFTH ANNUAL MEETING

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

STEVENS HOTEL, CHICAGO, ILLINOIS

APRIL 10–12, 1940

The annual spring meeting of the Association drew an attendance of approximately fourteen hundred geologists, paleontologists, geophysicists, oil men, and guests. The meeting was unique in many respects, first in being one of the few to be held outside of the Mid-Continent area, second in being the memorial twenty-fifth meeting celebrating a quarter century of active service, and thirdly in combining the entire program of meetings, and those of the Society of Exploration Geophysicists, and the Society of Economic Paleontologists and Mineralogists under one roof. The facilities of the Stevens

Officers of the Association. Seated, left to right: Henry A. Ley, president, 1939–40; L. C. Snider, president, 1940–41; John M. Vetter, vice-president, 1940–41. Standing, left to right: L. Murray Neumann, vice-president, 1939–40; Ed. W. Owen, secretary-treasurer, 1939–41; W. A. Ver Wiebe, editor, 1937–41.

Hotel, well known as the largest hotel in the world, completely and efficiently absorbed every need of all three organizations. All pre-convention reservations for rooms were made by the assigning of specific rooms and the customary convention-day crowding in the lobby was avoided.

The remarkable oil development of the Illinois basin was the guiding factor in bringing the annual meeting to Chicago. The large attendance attests to the wisdom of this policy. The smooth running of the technical programs, the well organized field trips and the excellent handling of the entertainment features, demonstrated careful planning by the general arrangements committee, under Verner Jones, general chairman, and his many assisting chairmen drawn largely from the membership of the Illinois Geological Survey.

The registration of members was held on the second-floor lobby and the

Officers of the Society of Economic Paleontologists and Mineralogists. Left to right: Gayle Scott, president, 1939-40; H. B. Stenzel, secretary-treasurer, 1939-41; Carey Croneis, president, 1940-41.

collection of scientific exhibits was displayed in the Boulevard Room on the same floor. The general meetings of the Association were held in the Grand Ball Room on the second floor. The geophysicists held their sessions in the Tower Ball Room. The paleontologists met in the South Ball Room.

One of the pre-convention features of striking interest was the informal dinner of the research committee followed by the open research meeting devoted to geochemical prospecting. A. I. Levorsen conducted the open forum and more than five hundred were in attendance. The discussion was a searching inquiry into the present status of geochemistry.

The meetings of the Association were opened Wednesday morning by the address of the president Henry A. Ley, of San Antonio. The secretary-treasurer, Ed. W. Owen, paid a touching tribute to the memory of Donald C.

Barton, George C. Matson, and Ralph D. Reed, three former presidents of the Association, who died during the past year.

A compliment and a testimonial of long and faithful service were paid to Miss Daisy Winifred Heath, editorial secretary of the Association, by editor Walter A. Ver Wiebe. Miss Heath, in the service of the Association since 1922, replied fittingly to her presentation.

On Wednesday night the Chicago University Alumni held an informal banquet, after which the doors were opened and about two hundred geologists and friends listened to an address by president Robert Maynard Hutchins, of the University.

Officers of the Society of Exploration Geophysicists. Left to right: W. T. Born, president, 1940–41; H. B. Peacock, vice-president, 1940–41; Andrew Gilmour, secretary-treasurer, 1940–41; R. D. Wyckoff, editor, 1940–41.

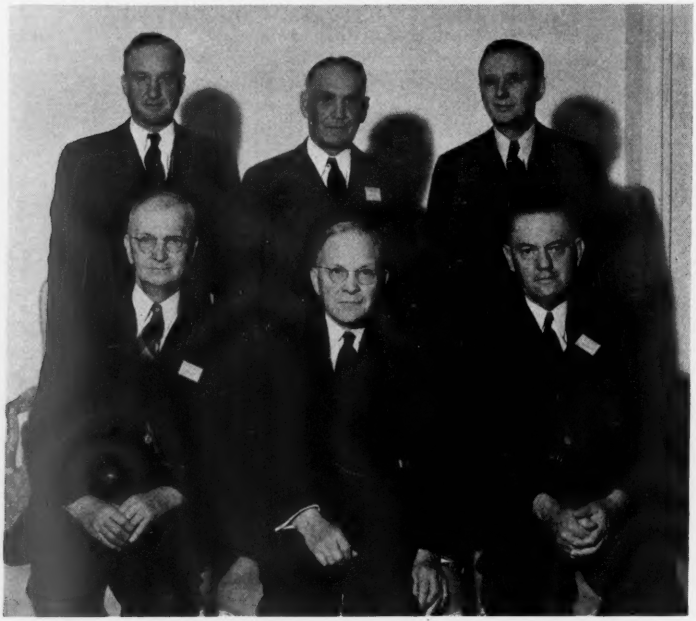
It is impractical here to list the many interesting and valuable papers presented before the Association. Thursday morning was devoted largely to the Illinois basin and the afternoon to the Michigan basin. Friday was given to the Gulf Coast, Mid-Continent, Appalachian, and California regions.

The election of Association officers for the coming year was carried out without contest. L. C. Snider, of Petroleum Advisers, Inc., New York, was elected president, and J. M. Vetter, Pan-American Producing Company, Houston, Texas, vice-president. Ed. W. Owen, secretary-treasurer, and W. A. Ver Wiebe, editor, were re-elected for another term.

The Society of Economic Paleontologists and Mineralogists elected Carey

Croneis, University of Chicago, Chicago, Illinois, president; John R. Sandidge, Magnolia Petroleum Company, San Antonio, Texas, vice-president; and H. B. Stenzel, Bureau of Economic Geology, University of Texas, Austin, Texas, was re-elected secretary-treasurer.

The Society of Exploration Geophysicists elected W. T. Born, Geophysical Research Corporation, Tulsa, Oklahoma, president; H. B. Peacock, Geophysical Service, Inc., Houston, Texas, vice-president; Andrew Gilmour,



Old timers. A few of the original members who attended the twenty-fifth annual meeting, photographed with president Snider. Seated, left to right: Charles N. Gould, L. C. Snider, Alexander Deussen. Standing, left to right: Jerry B. Newby, Charles H. Taylor, Walter R. Berger.

Amerada Petroleum Corporation, Tulsa, Oklahoma, secretary-treasurer; and R. D. Wyckoff, Gulf Research Corporation, Pittsburgh, Pennsylvania, editor.

The dinner-dance of the Association and affiliated societies was held on Thursday night in the Grand Ball Room of the Stevens. This feature, as usual, was the highlight of the local entertainment and, since held in one of the most remarkable ballrooms in the world, is deserving of special mention. The enormous ballroom, larger than any similar room in the world, is ornamented in the best Louis XIV style. The walls bear Rococo designs or incrustations of gold and many paintings are inset, done in the manner of the famous French artist Fragonard. Ten huge crystal chandeliers, designed and

Annual dinner dance scene in Grand Ball Room of Stevens Hotel, twenty-fifth annual meeting of the Association, April 11, 1940.

built in Paris, light the room. A balcony surrounds the entire room below which the walls are faced with marble and above which they are plastered. So vast is the room that it would easily accommodate a three-ring circus or professional indoor tennis matches.

In such a room more than six hundred geologists and their escorts dined and danced to the music of Lew Diamond and his National Broadcasting Orchestra. During a brief intermission the Dorothy Byton dancers, the Royal Whirlwinds on roller skates, and the Four Blenders, the voices of Pinnochio, gave a most creditable performance. The committee on entertainment arrangements is due the thanks of the Association on the high quality of the performers.

The Chicago convention was one of the best arranged and conducted in many years. It also made it possible for many members to visit the noted Field museum, the famous Adler planetarium, and the Shedd aquarium. In its broad diversity of interests the Chicago convention ranks with the outstanding 1937 convention in Los Angeles or the mid-year 1935 convention in Mexico City. The membership owes its thanks to the executive committee who brought the convention to Chicago and to the local committees who made it a success.

J. Brian Eby

Registration

The twenty-fifth annual meeting recorded the following attendance: 1,333 persons registered and were classified as 571 members, 55 associates, 450 non-member men, and 257 non-member women.

Executive Committee

Henry A. Ley, *President* . . . . . San Antonio, Texas
Donald C. Barton, *Past-President* (deceased) . . . . . Houston, Texas
L. Murray Neumann, *Vice-President* . . . . . Tulsa, Oklahoma
Ed. W. Owen, *Secretary-Treasurer* . . . . . San Antonio, Texas
Walter A. Ver Wiebe, *Editor* . . . . . Wichita, Kansas

The Society of Economic Paleontologists and Mineralogists

Gayle Scott, *President* . . . . . Fort Worth, Texas
H. L. Driver, *Vice-President* . . . . . Los Angeles, California
H. B. Stenzel, *Secretary-Treasurer* . . . . . Austin, Texas
E. H. Sellards, *Past-President* . . . . . Austin, Texas
S. G. Wissler, *Past-President* . . . . . Compton, California

The Society of Exploration Geophysicists

E. A. Eckhardt, *President* . . . . . Pittsburgh, Pennsylvania
W. T. Born, *Vice-President* . . . . . Tulsa, Oklahoma
J. H. Crowell, *Secretary-Treasurer* . . . . . Houston, Texas
R. D. Wyckoff, *Editor* . . . . . Pittsburgh, Pennsylvania
F. M. Kannenstine, *Past-President* . . . . . Houston, Texas
J. F. Gallie, *Business Manager* . . . . . Austin, Texas

The Illinois Geological Society

M. W. Fuller, *President* . . . . . Mattoon, Illinois
Verner Jones, *Past-President* . . . . . Mattoon, Illinois
B. Maxwell Miller, *Vice-President* . . . . . Mattoon, Illinois
J. G. Mitchell, *Secretary-Treasurer* . . . . . Olney, Illinois

CONVENTION COMMITTEES

GENERAL COMMITTEE

VERNER JONES, *General Chairman*

Chairmen:	*Regional subchairmen:*
Alfred H. Bell *Technical Program*	Eastern Interior Basin, M. W. Fuller Michigan Basin, R. B. Newcombe Appalachian Basin, M. G. Gulley Mid-Continent Region, Ira H. Cram Rocky Mountain Region, C. E. Dobbin Gulf Coast Region, K. H. Crandall California Region, E. R. Atwill
J. V. Howell *Arrangements*	
Mrs. Carl B. Anderson *Ladies*	Mrs. Theron Wasson, Mrs. D. J. Fisher, Mrs. C. J. Hares
M. M. Leighton *Field Trips*	R. E. Esarey, J. M. Weller, H. B. Willman, J Harlen Bretz, D. J. Fisher, G. E. Ekblaw
Carey Croneis *Technical Equipment*	Edson S. Bastin, D. J. Fisher
E. W. Ellsworth *Finance*	R. E. Duty, Walter Johnson, Stanley G. Elder, Kenneth L. Gow, Jack H. Campbell, James L. Carlton, Clarence E. Brehm, Warren L. Calvert, Duane C. Randall, J. Rex McGehee, James G. Mitchell
Don L. Carroll *Publicity and Exhibits*	W. A. Clark, Jr., Richard B. Rutledge, A. J. W. Headlee, Albert Gregersen, Charles W. Carter, Howard W. Handley
E. F. Stratton *Dinner Dance*	C. T. Casebeer, C. P. Parsons, B. M. Miller, B. H. Richards, Jr.
L. M. Clark *Registration and Reception*	Paul F. Osborne, K. A. Simmons, Kendall E. Born, George V. Cohee

SCHEDULE OF EVENTS

MONDAY, April 8

MORNING

10:00 Executive Committee, Henry A. Ley, Chairman. President's Suite.

AFTERNOON AND EVENING

1:00 Registration. Opposite Elevators, Second Floor.
8:00 S.E.G. Executive Committee. Private Dining Room No. 6, Third Floor.

TUESDAY, APRIL 9

MORNING

8:00 Pre-Convention Field Trip, Morris Area.
8:00 Registration, Opposite Elevators, Second Floor.
Scientific Exhibits. Boulevard Room, Second Floor.

9:00 Committee on Applications of Geology, C. E. Dobbin, Chairman. Private Dining Room No. 9, Third Floor.
10:00 Society of Exploration Geophysicists, Technical Session. Upper Tower Ball Room
10:00 Business Committee, L. C. Morgan, Chairman. Private Dining Room No. 1, Third Floor.
10:00 Committee for Publication, R. E. Rettger, Chairman. Private Dining Room No. 10, Third Floor.
10:00 Research Committee, A. I. Levorsen, Chairman. Private Dining Room No. 11, Third Floor.

AFTERNOON

12:30 S.E.G. Luncheon. South Ball Room, Third Floor.
2:00 S.E.G. Technical Session. Upper Tower Ball Room.
2:00 Research Committee Conference Groups:
"Sedimentation and Reservoir Rock Conditions," E. Wayne Galliher, Leader. Private Dining Room No. 9, Third Floor.
"Origin and Evolution of Oil," M. G. Cheney, Leader. Private Dining Room No. 10, Third Floor.
"Migration and Accumulation of Oil," F. M. Van Tuyl, Leader. Private Dining Room No. 11, Third Floor.
"Relation of Oil Analyses to Stratigraphy," N. W. Bass, Leader. Private Dining Room No. 4, Third Floor.
"Oil-Field Waters," L. C. Case, Leader. Private Dining Room No. 2, Third Floor.

EVENING

6:30 Informal Annual Dinner for all interested, sponsored by Research Committee. West Ball Room. Third Floor. Please buy tickets early at Registration Desk. Special tables for Foreign geology and for Permian conference.
8:00 Open annual meeting, Research Committee, A. I. Levorsen, Chairman. Grand Ball Room, Second Floor. "Geochemical Exploration."

WEDNESDAY, APRIL 10

MORNING

7:00 Special train arrives from South and Southwest.
7:30 Registration. Opposite Elevators, Second Floor.
8:00 Scientific Exhibits. Boulevard Room, Second Floor.
9:30 Opening General Session. Technical and Joint Session with Society of Economic Paleontologists and Mineralogists and Society of Exploration Geophysicists. Grand Ball Room, Second Floor.

AFTERNOON

1:30 Announcements, Nomination of Officers, Appointment of Committees. Grand Ball Room, Second Floor.
2:00 Technical Session, sponsored by Research Committee, "Symposium on New Ideas in Petroleum Exploration." Grand Ball Room, Second Floor.
2:00 S.E.G. Technical Session. Upper Tower Ball Room.
4:00 S.E.P.M. Research Committee. Private Dining Room No. 5, Third Floor.
5:00 S.E.P.M. Council Meeting. Private Dining Room No. 6, Third Floor.

EVENING

6:45 University of Chicago Reception. North Assembly Room, Third Floor. (Adjacent to North Ball Room.)
7:15 University of Chicago Informal Banquet. North Ball Room, Third Floor (Service will start exactly at 7:15.)
8:55 Address by Robert Maynard Hutchins, President, University of Chicago. North Ball Room, Third Floor. (Seating arrangements will be provided for those not attending banquet but who wish to hear Dr. Hutchins speak.)

THURSDAY, APRIL 11

MORNING

8:00 Registration. Opposite Elevators, Second Floor.
Scientific Exhibits. Boulevard Room, Second Floor.
Committee on Geological Names and Correlations, J. G. Bartram, Chairman. Private Dining Room No. 9, Third Floor. Breakfast Meeting.
9:00 Technical Session. Eastern Interior Basin. Grand Ball Room, Second Floor.
9:00 S.E.P.M. Technical Session. South Ball Room, Third Floor.
9:30 S.E.G. Technical Session. Upper Tower Ball Room.
12:00 Ladies. Luncheon and Style Show, Marshall Field's.

AFTERNOON

1:30 Technical Session. Michigan and Appalachian Basin. Grand Ball Room, Second Floor.
1:30 S.E.P.M. Technical Session. South Ball Room, Third Floor.
1:30 S.E.G. Technical Session. Upper Tower Ball Room.
2:00 A.A.P.G. Concurrent Technical Session. General Papers. North Ball Room, Third Floor.

EVENING

7:30 Banquet, followed by dancing. Grand Ball Room, Second Floor. Per plate, $3.00.

FRIDAY, APRIL 12

MORNING

8:00 Registration. Opposite Elevators, Second Floor.
Scientific Exhibits. Boulevard Room.
8:30 Twenty-fifth Annual Business Meeting. Announcement of Elections. Grand Ball Room.
9:30 Technical Session. Mid-Continent and Rocky Mountain Regions. Grand Ball Room.
9:30 S.E.P.M. Technical Session. South Ball Room, Third Floor.
10:00 Executive Committees, 1939 and 1940, Joint Meeting. Private Dining Room No. 5, Third Floor.
11:00 S.E.P.M. Annual Business Meeting. South Ball Room, Third Floor.

AFTERNOON

2:00 Technical Session. Gulf Coast and California Regions. Grand Ball Room.

SATURDAY, APRIL 13

Field Trips to LaSalle, Illinois, Area, and Kentland, Indiana, Area.

TECHNICAL PROGRAM

WEDNESDAY MORNING, APRIL 10
GRAND BALL ROOM, STEVENS HOTEL

GENERAL SESSION

Joint Session with Society of Economic Paleontologists and Mineralogists and Society of Exploration Geophysicists
9:30 A. M.–12:00 Noon

Presiding: HENRY A. LEY, VERNER JONES

1. M. M. LEIGHTON, Chief, Illinois Geological Survey, Urbana, Illinois
9:30 *Address of Welcome* (10 minutes)

2. HENRY A. LEY, President of the Association
9:40 *Response* (10 minutes)

3. ED. W. OWEN, Secretary-Treasurer of the Association
9:50 *Memorials* (20 minutes)

4. HENRY A. LEY, President of the Association
10:10 *Presidential address: This Association* (20 minutes)

Intermission 10 minutes

5. GAYLE SCOTT, President of the Society of Economic Paleontologists and Mineralogists
10:40 *Presidential address: Ecological Factors Controlling the Distribution of Cretaceous Ammonoids in the Texas Area* (20 minutes)

6. E. A. ECKHARDT, President of the Society of Exploration Geophysicists
11:00 *Presidential address: The Partnership of Geology and Geophysics in Prospecting for Oil* (20 minutes)

7. R. W. RICHARDS, U. S. Geological Survey, Washington, D. C.
11:20 *New Oil Supply and Production in the United States, 1913–1919* (15 minutes)

8. F. H. LAHEE, Chief Geologist, Sun Oil Company, Dallas Texas
11:35 *Results of Exploratory Drilling in the United States in 1939* (15 minutes)

WEDNESDAY AFTERNOON, APRIL 10

GRAND BALL ROOM, STEVENS HOTEL

NOMINATION OF OFFICERS

1:30 P.M.–2:00 P.M.

Presiding: HENRY A. LEY

RESEARCH COMMITTEE SYMPOSIUM:

"New Ideas in Petroleum Exploration with Their Significance to Petroleum Geology"

2:00 P.M.–4:30 P.M.

Presiding: A. I. LEVORSEN, MONROE G. CHENEY

1. A. I. LEVORSEN, Chairman Research Committee, Tulsa, Oklahoma
2:00 *Introduction* (15 minutes)

2. PAUL E. FITZGERALD, Dowell Incorporated, Tulsa, Oklahoma
2:15 *Chemical Engineering* (15 minutes)

3. C. V. MILLIKAN, Amerada Petroleum Corporation, Tulsa, Oklahoma
2:30 *Petroleum Engineering* (15 minutes)

4. E. A. ECKHARDT, Gulf Research and Development Company, Pittsburgh, Pennsylvania
2:45 *Geophysics* (15 minutes)

5. E. E. ROSAIRE, Subterrex, Houston, Texas
3:00 *Geochemical Exploration (Soil Analysis)* (15 minutes)

6. F. H. LAHEE, Sun Oil Company, Dallas, Texas
3:15 *Where Will Our Young Graduates in Petroleum Geology Acquire Field Experience?* (20 minutes)

7. E. DEGOLYER, DeGolyer, MacNaughton, and McGhee, Dallas, Texas
3:35 *Future Position of Petroleum Geology in the Oil Industry* (20 minutes)

A brief intermission will follow the last paper at which time the audience may send written questions or comments to the platform and those who wish to speak may move close to the microphones. The meeting will then continue as an open forum.

THURSDAY MORNING, APRIL 11

GRAND BALL ROOM, STEVENS HOTEL

EASTERN INTERIOR BASIN

9:00 A.M.–12:00 Noon

Presiding: F. W. DEWOLF, M. W. FULLER

1. ALFRED H. BELL, Illinois Geological Survey, Urbana, Illinois
9:00 *Developments in the Eastern Interior Basin, 1939 and 1940* (10 minutes)

2. C. J. Hares, Ohio Oil Company, Marshall, Illinois
   9:10 *Review of Structural Discoveries in the Illinois Basin* (25 minutes including discussion)
3. P. L. Dana and E. H. Scobey, Gulf Refining Company, Mattoon, Illinois
   9:35 *A Cross-Section of the Chester Series of the Illinois Basin* (30 minutes, including discussion)
4. Duane C. Randall, The Carter Oil Company, St. Elmo, Illinois
   10:05 *Geology and Development of the Loudon Pool, Fayette County, Illinois* (25 minutes, including discussion)
5. L. E. Workman, Illinois Geological Survey, Urbana, Illinois
   10:30 *Subsurface Geology of the Devonian in Illinois* (35 minutes, including discussion)
6. Charles W. Wilson, Jr., Vanderbilt University, Nashville, Tennessee
   Kendall E. Born, State Division of Geology, Nashville, Tennessee
   11:05 *Geology of the Nashville Dome* (20 minutes, including discussion)
7. Kendall E. Born, State Division of Geology, Nashville, Tennessee
   11:25 *Paleozoic Wells in the Mississippi Embayment in Tennessee* (10 minutes, including discussion)
8. C. R. Longwell, Yale University, New Haven, Connecticut
   Charles H. Behre, Jr., Northwestern University, Evanston Illinois
   11:35 *Tectonic Map of North-Central United States* (15 minutes, including discussion)

Thursday Afternoon, April 11

Grand Ball Room, Stevens Hotel

MICHIGAN AND APPALACHIAN BASINS

1:30 P.M.–4:30 P.M.

Presiding: M. G. Gulley, R. B. Newcombe

1. R. B. Newcombe, Consulting Geologist, Grand Rapids, Michigan
   1:30 *Developments in Michigan During 1939* (10 minutes)
2. J. B. Maebius, Gulf Refining Company, Saginaw, Michigan
   1:40 *Temple Field, Freeman-Redding Pools, Clare County, Michigan* (20 minutes, including discussion)
3. C. H. Riggs, Department of Conservation, Grand Rapids, Michigan
   2:00 *Geology of the Walker Oil Field* (20 minutes, including discussion)
4. Margaret Stearns Bishop, Consulting Geologist, Paw Paw, Michigan
   2:20 *Isopachous Studies of the Ellsworth to Traverse Limestone Section of Southwestern Michigan* (10 minutes)
5. Carl C. Addison, The Pure Oil Company, Saginaw, Michigan
   2:30 *Buckeye Oil Field, Gladwin County, Michigan* (15 minutes)
6. Donald B. MacLachlan, Wayne University, Detroit, Michigan
   2:45 *Structure in Southeastern Ontario and the Thumb of Michigan as Revealed by Late Quaternary Warping* (15 minutes)
7. Thurman H. Myers, Carnegie Natural Gas Company, Pittsburgh, Pennsylvania
   3:00 *Deep Sand Developments in the Appalachian Region During 1939* (10 minutes)
8. R. E. Sherrill, University of Pittsburgh, Pittsburgh, Pennsylvania
   3:10 *Some Problems of Appalachian Structure* (25 minutes)
9. Robert C. Lafferty, The Owens, Libbey-Owens Gas Department, Charleston, West Virginia
   3:35 *Some Observations Concerning the Sedimentary History of the Central Part of the Appalachian Basin* (25 minutes)
10. Harold R. Wanless, University of Illinois, Urbana, Illinois
    4:00 *Pennsylvania Sedimentation in a Part of the Southern Appalachian Coal Fields* (20 minutes)

11. Paul H. Price, State Geologist, Morgantown, West Virginia
H. P. Woodward, University of Newark, Newark, New Jersey
4:20 *The Devonian System of West Virginia* (20 minutes)

PAPER BY TITLE

12. Lucille Hale, Department of Conservation, Lansing, Michigan
A Study of the Sedimentation and Stratigraphy of the Lower Mississippian in Western Michigan

CONCURRENT SESSION

THURSDAY AFTERNOON, APRIL 11
WEST BALL ROOM, STEVENS HOTEL

GENERAL PAPERS

2:00 P.M.–5:00 P.M.

Presiding: C. H. Behre, Jr., D. J. Fisher

1. F. B. Plummer, Bureau of Economic Geology, Austin, Texas
2:00 *Water Cones and Water Sheaths in Oil Wells* (30 minutes, including discussion)
2. F. M. Van Tuyl, Colorado School of Mines, Golden, Colorado
W. A. Waldschmidt
John Baird
2:30 *Compaction and Flushing of Oil Sands* (25 minutes, including discussion)
3. E. Berl, Carnegie Institute of Technology, Pittsburgh, Pennsylvania
2:55 *The Role of Carbohydrates in the Formation of Oil and Bituminous Coals* (25 minutes)
4. Max W. Ball, Abasand Oils, Ltd., Edmonton, Alberta, Canada
3:20 *Steps in the Formation of an Oil Field* (20 minutes, including discussion)
5. W. H. Twenhofel, University of Wisconsin, Madison, Wisconsin
3:40 *The Sediments of Lakes* (25 minutes, including discussion)
6. V. E. McKelvey, University of Wisconsin, Madison, Wisconsin
4:05 *Beach Sediments of Trout Lake, Wisconsin* (15 minutes, including discussion)
7. W. P. Jenny, Consulting Geophysicist, Houston, Texas
4:20 *Geological Problems in the Interpretation of the Earth's Major Regional and Local Anomalies* (20 minutes, including discussion)

PAPERS BY TITLE

8. Eugene McDermott, Geophysical Service, Inc., Dallas, Texas
Geochemical Exploration (Soil Analysis) with Some Speculation as to the Genesis of Oil and Gas Accumulations
9. Ivan J. Fenn, Subterrex, Houston, Texas
An Hypothesis for the Origin of Certain Geochemical Anomalies Associated with Oil Fields

FRIDAY MORNING, APRIL 12
GRAND BALL ROOM, STEVENS HOTEL

ANNUAL BUSINESS MEETING

8:30 A.M.–9:30 A.M.

Presiding: Henry A. Ley

MID-CONTINENT AND ROCKY MOUNTAIN REGIONS

9:30 A.M.–12:30 P.M.

Presiding: Ira H. Cram, C. E. Dobbin

1. Edward A. Koester, Darby Petroleum Corporation, Wichita, Kansas
9:30 *Recent Developments in the North Mid-Continent* (15 minutes)

2. LEWIS W. MACNAUGHTON, DeGolyer, MacNaughton, and McGhee, Dallas, Texas
9:45 *Recent Developments in the South Mid-Continent* (20 minutes, including discussion)

3. IRA H. CRAM, The Pure Oil Company, Tulsa, Oklahoma
10:05 *Stratigraphy and Structure of the Northeastern Wichita Mountains, Oklahoma* (20 minutes, including discussion)

4. THOMAS A. HENDRICKS, U. S. Geological Survey, Washington, D. C.
10:25 *Structure of the Western Part of the Ouachita Mountains* (20 minutes, including discussion)

5. MALVIN G. HOFFMAN, Midco Oil Corporation, Tulsa, Oklahoma
10:45 *The Structural History of the Billings Field Interpreted in Terms of Isostasy* (20 minutes, including discussion)

6. GLENN G. BARTLE, University of Kansas City, Kansas City, Missouri
RUFUS M. SMITH, Panhandle Eastern Pipe Line Company, Kansas City, Missouri
11:05 *The Relative Porosity and Permeability of the Producing Formations of the Hugoton Field as Indicated by Gas Withdrawals and Pressure Declines* (20 minutes, including discussion)

7. C. E. DOBBIN, U. S. Geological Survey, Denver, Colorado
11:25 *Developments in the Rocky Mountain Region in 1939* (5 minutes)

8. W. O. THOMPSON, University of Colorado, Boulder, Colorado
J. M. KIRBY, The California Company, Denver, Colorado
11:30 *Permo-Pennsylvanian Stratigraphy between Colorado Springs, Colorado, and the Black Hills, South Dakota* (15 minutes)

9. C. E. ERDMANN, U. S. Geological Survey, Denver, Colorado
11:45 *Principles of Oil Accumulation in the Cut Bank District, Montana* (15 minutes)

10. E. B. BRANSON, University of Missouri, Rolla, Missouri
C. C. BRANSON, Brown University, Providence, Rhode Island
12:00 *Stratigraphy and Structures of the Wind River Mountains of Wyoming* (15 minutes)

11. J. T. STARK, W. E. POWERS, A. L. HOWLAND, C. H. BEHRE, JR., Northwestern University, Evanston, Illinois
D. B. GOULD, Colorado College, Colorado Springs, Colorado
J. H. JOHNSON, Colorado School of Mines, Colorado
12:15 *The Structure of South Park, Colorado* (5 minutes)

PAPERS BY TITLE

12. KARL A. MYGDAL, The Pure Oil Company, Wichita Falls, Texas
Developments in North and West Central Texas—1939

13. CHARLES E. DECKER, University of Oklahoma, Norman, Oklahoma
Additional Information on the Simpson Group of Oklahoma

14. R. L. CLIFTON, Champlin Refining Company, Enid, Oklahoma
The San Andres Group in Oklahoma and Adjacent Areas

15. W. B. LANG, U. S. Geological Survey, Washington, D. C.
The Fletcher Member of Salado Formation

16. CHALMER J. ROY, Louisiana State University, University, Louisiana
Marine Limestone in the Fountain Formation (Pennsylvanian) near Colorado Springs, Colorado

17. F. B. PLUMMER, Bureau of Economic Geology, Austin, Texas
B. F. GRANT, Bureau of Economic Geology, Austin, Texas
Geology of the Lampasas Inlier of Paleozoic Rocks in Central Texas

FRIDAY AFTERNOON, APRIL 12
GRAND BALL ROOM, STEVENS HOTEL
CALIFORNIA AND GULF COAST REGIONS
2:00 P.M.–5:00 P.M.

Presiding: ED W. OWEN, K. H. CRANDALL

1. E. ROBERT ATWILL, Union Oil Company of California, Los Angeles, California
2:00 *Significant Developments in California—1939* (20 minutes, including discussion)

2. ROY M. BARNES, Continental Oil Company, Los Angeles, California
2:20 *Twenty Years of Petroleum Geology in California* (20 minutes, including discussion)

3. FRED A. MENKEN, Tide Water Associated Oil Company, San Francisco, California
2:40 *Eocene Exploration in California* (20 minutes, including discussion)

4. L. B. HERRING, Geologist, Corpus Christi, Texas
3:00 *Developments and Status of Oil Reserves in South Texas, 1939* (20 minutes)

5. O. L. BRACE, Consulting Geologist, Houston, Texas
3:20 *Review of Developments in 1939, Gulf Coast of Upper Texas and Louisiana* (20 minutes)

6. F. W. ROLSHAUSEN, Humble Oil & Refining Company, Houston, Texas
3:40 *Notes on Fossiliferous Frio* (15 minutes, including discussion)

7. J. A. CULBERTSON, Continental Oil Company, Houston, Texas
3:55 *The Downdip Wilcox (Eocene) of Coastal Texas and Louisiana* (25 minutes, including discussion)

8. FRED W. BATES, Geologist, Lafayette, Louisiana
4:20 *Geology of the Eola Field, Avoyelles Parish, Louisiana* (20 minutes, including discussion)

9. BARNEY FISHER, Geologist, Coronado Corporation, Dallas, Texas
4:40 *The La Rosa Field, Refugio County, Texas* (20 minutes, including discussion)

PAPERS BY TITLE

10. M. M. KORNFELD, Consulting Paleontologist, Houston, Texas
The Post-Vicksburg Hackberry Zone in the Gulf Coast

11. H. B. STENZEL, Bureau of Economic Geology, University of Texas, Austin, Texas
A New Zone in the Cook Mountain Formation, the Crassatella texalta Harris—Turritella cortezi Bowles Zone

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
THURSDAY MORNING, APRIL 11
SOUTH BALL ROOM, STEVENS HOTEL
TECHNICAL SESSION
9:00 A.M.–12:00 Noon

Presiding: GAYLE SCOTT

1. THOMAS G. PAYNE, University of Chicago, Chicago, Illinois
9:30 *Recurrent Facies and Faunules of the New York Middle Devonian* (15 minutes)

2. W. FARREN HOOVER, Consulting Geologist, Mt. Vernon, Illinois
9:45 *A Correlation of the Subsurface Devonian of Sandoval, Illinois, Pool with the Devonian Outcrop in Southwest Illinois* (15 minutes)

3. R. L. CLIFTON, Champlin Refining Company, Enid, Oklahoma
10:00 *Invertebrate Faunas from the Blaine and the Dog Creek Formations of the Leonard Series* (15 minutes)

4. WILLIAM F. READ, University of Chicago, Chicago, Illinois
   10:15 *Association of West Texas Permian Vertebrates and Plants with Marine Invertebrates* (15 minutes)

5. JOHN R. BALL, Northwestern University, Evanston, Illinois
   10:30 *Some Silurian Correlations in the Lower Mississippi Drainage Basin* (15 minutes)

6. WM. H. EASTON, University of Chicago, Chicago, Illinois
   10:45 *Mid-Carboniferous Strata of Northern Arkansas* (10 minutes)

7. NORMAN D. NEWELL, University of Wisconsin, Madison, Wisconsin
   BERNHARD KUMMEL, University of Wisconsin, Madison, Wisconsin
   10:55 *Permo-Triassic Boundary in Southeastern Idaho and Western Wyoming* (10 minutes)

8. LLOYD WILLIAM STEPHENSON, U. S. Geological Survey, Washington, D. C.
   11:05 *Summary of Faunal Studies of the Navarro Group of Texas* (20 minutes)

9. JULIA GARDNER, U. S. Geological Survey, Washington, D. C.
   11:25 *Analysis of the Midway Fauna of the Western Gulf Province* (15 minutes)

10. GROVER MURRAY, JR., Louisiana State University, Baton Rouge, Louisiana
    11:40 *Comparison of the Ostracod Fauna of the Gosport at Claiborne Bluff, Alabama, with Faunas of Known Jackson and Claiborne Localities* (10 minutes)

11. MAX B. PAYNE, Richfield Oil Corporation, Bakersfield, California
    11:50 *Type Moreno Cretaceous and Superjacent Eocene, Panoche Hills, California* (10 minutes)

THURSDAY AFTERNOON, APRIL 11

SOUTH BALL ROOM, STEVENS HOTEL

TECHNICAL SESSION

1:30 P.M.–4:30 P.M.

Presiding: CAREY CRONEIS

1. EDWARD A. FREDERICKSON, University of Wisconsin, Madison, Wisconsin
   1:30 *Cambro-Ordovician Trilobites from Oklahoma* (15 minutes)

2. M. S. CHAPPARS, University of Chicago, Chicago, Illinois
   ALFRED R. LOEBLICH, JR., University of Chicago, Chicago, Illinois
   1:45 *The Genus Constellaria in North America* (10 minutes)

3. HAROLD B. RENFRO, University of Wisconsin, Madison, Wisconsin
   1:55 *Pelecypod Fauna of the Permian Satanka Shale* (15 minutes)

4. NORMAN D. NEWELL, University of Wisconsin, Madison, Wisconsin
   2:10 *Phylogeny of Myalina s.s.* (10 minutes)

5. HEINZ A. LOEWENSTAMM, University of Chicago, Chicago, Illinois
   2:20 *The Development of the Root Ancyrocrinus* (10 minutes)

6. R. HENDEE SMITH, Louisiana State University, Baton Rouge, Louisiana
   2:30 *Micropaleontology and Stratigraphy of a Deep Well at Niceville, Okaloosa County, Florida* (15 minutes)

7. ALFRED FISCHER, University of Wisconsin, Madison, Wisconsin
   2:45 *A Belemnite from the Permian of Greenland* (15 minutes)

8. GROVER MURRAY, JR., Louisiana State University, Baton Rouge, Louisiana
   KEITH M. HUSSEY, Louisiana State University, Baton Rouge, Louisiana
   3:00 *Tertiary Ostracoda of the Genera Alatacythere and Brachycythere* (15 minutes)

9. HELEN TAPPAN LOEBLICH, University of Chicago, Chicago, Illinois
   3:15 *New Arenaceous Foraminifera from the Woodbine Sand of Northern Texas* (10 minutes)

10. HUBERT G. SCHENCK, Stanford University, Stanford University, California
3:25 *Economically Important Microfossils* (20 minutes)

11. M. L. THOMPSON, New Mexico School of Mines, Socorro, New Mexico
J. C. HAZZARD
3:45 *Permian Fusulinids from the Providence Mountains, California* (15 minutes)

12. M. L. THOMPSON, New Mexico School of Mines, Socorro, New Mexico
H. J. BISSELL
4:00 *Pennsylvanian and Permian Fusulinids of the Wasatch Mountains, Utah* (15 minutes)

13. L. G. HENBEST, U. S. Geological Survey, Washington, D. C.
S. A. BERTHIAUME, Cornell University, Ithaca, New York
4:15 *Fusulinidae from the Crooked River Basin, Oregon* (15 minutes)

PAPERS BY TITLE

14. CHARLES E. DECKER, University of Oklahoma, Norman, Oklahoma
Graptolites from the Haragan Formation (Lower Devonian) of Oklahoma

15. A. K. MILLER AND W. M. FURNISH, State University of Iowa, Iowa City, Iowa
Pennsylvanian Ammonoid Zones in the Northern Mid-Continent Region

16. RAYMOND C. MOORE, University of Kansas, Lawrence, Kansas
Asymmetrical Crinoids with Unbranched Arms

FRIDAY MORNING, APRIL 12

SOUTH BALL ROOM, STEVENS HOTEL

TECHNICAL SESSION

9:30 A.M.–12:00 Noon

Presiding: W. H. TWENHOFEL

1. E. C. DAPPLES, Northwestern University, Evanston, Illinois
9:30 *The Sedimentary Characteristics of the Lonsdale Limestone* (15 minutes)

2. N. ALLEN RILEY, University of Chicago, Chicago, Illinois
9:45 *A Simplified Method of Studying the Shapes of Sedimentary Particles* (10 minutes)

3. BENJAMIN H. BURMA, University of Wisconsin, Madison, Wisconsin
9:55 *Statistical Analysis Applied to Fusulinids* (25 minutes)

4. F. J. PETTIJOHN, University of Chicago, Chicago, Illinois
10:10 *Relative Abundance of Size-Grades of Clastic Sediments* (15 minutes)

5. GEORGE H. OTTO, U. S. Soil Conservation Service, Pasadena, California
10:25 *Field Sampling Errors in Relation to Typical Beaches of Texas, Florida, and California* (10 minutes)

6. GEORGE H. OTTO, U. S. Soil Conservation Service, Pasadena, California
MELVIN N. LEVET
10:35 *Effect of Sieving Time and Sample Weight on the Statistics of Sieve Analyses of Quartz Sand* (15 minutes)

7. W. M. COGEN, Shell Oil Company, Houston, Texas
10:50 *Heavy Mineral Zones of Louisiana Gulf Coast Sediments* (10 minutes)
11:00 BUSINESS MEETING—*Presiding Officer*, GAYLE SCOTT

SOCIETY OF EXPLORATION GEOPHYSICISTS

TUESDAY MORNING, APRIL 9

UPPER TOWER BALL ROOM, STEVENS HOTEL

Presiding: E. A. ECKHARDT

1. M. W. Gay, Gulf Research and Development Company, Pittsburgh, Pennsylvania
   Relative Gravity Measurements Using Precision Pendulum Equipment
2. M. O. Gibson, Shell Oil Company, Inc.
   Network Adjustment by Least Squares—Alternative Formulation and Solution by Iteration
3. S. S. West, Stanolind Oil and Gas Company, Tulsa, Oklahoma
   The Effect of Density on Seismic Reflections
4. Roland F. Beers, The Geotechnical Corporation, Dallas, Texas
   Resolution Control in Seismic Surveys
5. Thomas Wiancko and Martin Eichelberger, United Geophysical Company, Pasadena, California
   Combination of Wave Transients
6. Irwin Roman, Geological Survey, United States Department of the Interior
   Evaluation of Magnetic Anomalies by Means of Scales

TUESDAY AFTERNOON, APRIL 9

Presiding: L. M. KANNENSTINE

7. W. M. Rust, Jr., Humble Oil and Refining Company, Houston, Texas
   Electrical Prospecting Methods
8. E. A. Eckhardt, Gulf Research and Development Company, Pittsburgh, Pennsylvania
   A Brief History of the Gravity Method of Prospecting
9. B. B. Weatherby, Geophysical Research Corporation, Tulsa, Oklahoma
   The History and Development of Seismic Prospecting
10. James B. Macelwane, Director, Department of Geophysics, St. Louis University, St. Louis, Missouri
    Fifteen Years of Geophysics: A Chapter in the Exploration of the United States, 1924–1939
11. E. E. Rosaire, Subterrex, Houston, Texas
    A Perspective of Exploration for Petroleum
12. R. Thomas Sanderson, Western Geophysical Company, Los Angeles, California
    Some Neglected Aspects of Chemical Exploration
13. W. T. Born, Geophysical Research Corporation, Tulsa, Oklahoma
    Geophysical Applications in the Production of Oil

THURSDAY MORNING, APRIL 11

Presiding: J. C. KARCHER

14. J. M. Kendall, Geophysical Research Corporation, Tulsa, Oklahoma
    The Range of Amplitudes in Seismic Reflection Records
15. W. T. Born, Geophysical Research Corporation, Tulsa, Oklahoma
    A Note on the Attenuation Constant of Earth Materials
16. Norman Ricker, Carter Oil Company, Tulsa, Oklahoma
    On the Form and Nature of Seismic Waves and the Structure of Seismograms
17. R. D. Wyckoff, Gulf Research and Development Company, Pittsburgh, Pennsylvania
    The Gulf Gravimeter
18. T. B. Pepper, Gulf Research and Development Company, Pittsburgh, Pennsylvania
    The Gulf Underwater Gravimeter
19. W. G. Green and R. E. Fearon, Well Surveys, Inc., Tulsa, Oklahoma
    Some Properties of Radioactivity Logs
20. E. D. Lynton, Standard Oil Company of California, Los Angeles, California
    The Mechanics of the Upside Down Core

21. Herbert Hoover, Jr., and E. E. Hoskins, United Geophysical Company, Pasadena, California
 Modern Seismic Amplifiers (Read by title)
22. Harold Washburn and Raymond C. Oleson, United Geophysical Company, Pasadena, California
 Transient Testing of Seismic Recording Apparatus

THURSDAY AFTERNOON, APRIL 11

Presiding: L. W. BLAU

23. Thomas A. Elkins, Gulf Research and Development Company, Pittsburgh, Pennsylvania
 The Reliability, on the Basis of Probability Considerations, of Geophysical Anomalies
24. M. B. Widess and N. A. Haskell, Western Geophysical Company, Los Angeles, California
 The Computation and Mapping of Seismic Reflection Data
25. N. N. Zirbel, Independent Exploration Company, Houston, Texas
 Michigan Weathering
26. Harold Washburn and Harold Wiley, United Geophysical Company, Pasadena, California
 The Effect of the Placement of a Seismometer on Its Response Characteristics
27. Alfred Wolf, Geophysical Research Corporation, Tulsa, Oklahoma
 The Time Delay of a Wave Group in the Weathered Layer
28. W. R. Ransone and F. E. Romberg, Geophysical Service, Inc., Dallas, Texas
 Average Vertical Velocities from Refraction and Reflection Profiles
29. Raymond A. Peterson, United Geophysical Company, Pasadena, California
 A Transformed Wave Front Chart
30. H. J. McCready, Mott-Smith Corporation, Puerto Wilches, Santander, Colombia S.A.
 Shot Hole Characteristics in Reflection Seismology
31. Sylvain J. Pirson, Pennsylvania State College, State College, Pennsylvania
 A Critical Survey of Recent Developments in Geochemical Prospecting

---

MINUTES, TWENTY-FIFTH ANNUAL BUSINESS MEETING STEVENS HOTEL, CHICAGO, ILLINOIS

APRIL 10–12, 1940

HENRY A. LEY, *presiding*

The meeting was called to order at 1:30 P.M., April 10, 1940, by Henry A. Ley, president, Ed. W. Owen serving as secretary.

1. *Nominations of officers.*—The president called for nominations of officers of the Association for the ensuing year. The following nominations were made.

For president:	L. C. SNIDER, nominated by W. B. Wilson
For vice-president:	JOHN M. VETTER, nominated by R. G. Reese
For secretary-treasurer:	ED. W. OWEN, nominated by A. R. Denison
For editor:	W. A. VER WIEBE, nominated by John L. Rich

There being only one nominee for the offices of president, vice-president, secretary-treasurer, and editor, the motion was made, seconded, and carried that the secretary be authorized to cast a unanimous ballot for the nominees for these offices.

The meeting was recessed at 2:15 P.M. until 9:00 A.M., April 12, 1940.

The recessed meeting was called to order at 9:00 A.M., April 12, 1940, by Henry A. Ley, presiding.

2. *Reading of minutes.*—It was moved, seconded, and carried that the

reading of the minutes of the annual meeting held at Oklahoma City, Oklahoma, March 22–24, 1939, be dispensed with inasmuch as they had been published in the *Bulletin*.

3. *Report of officers.*—The reports of president Henry A. Ley, editor W. A. Ver Wiebe, and secretary-treasurer Ed. W. Owen were presented (Exhibits I, II, III).

4. *Report of business committee.*—The report of the business committee (Exhibit IV) was read by chairman L. C. Morgan. It was moved, seconded, and carried that the report be received and placed on file.

It was moved, seconded, and carried that the recommendation of the business committee on the matter of filling vacancies in the executive committee be adopted.

[The reports of the committee on geologic names and correlations, John G. Bartram, chairman; of the research committee, A. I. Levorsen, chairman; of the committee on applications of geology, C. E. Dobbin, chairman; of the committee for publication, R. E. Rettger, chairman; and of the representative of the Association on the National Research Council Division of Geology and Geography, F. H. Lahee, representative, appear as Exhibits V, VI, VII, VIII, IX, respectively.]

5. *Report of the resolutions committee.*—The report of the resolutions committee (Exhibit X) was read by Carleton D. Speed, chairman. It was moved, seconded, and carried that the report be adopted.

6. An invitation to hold the twenty-sixth annual meeting in Denver, Colorado, was extended by C. E. Dobbin, Rocky Mountain representative.

7. The president read an invitation from the Mayor of Galveston, Texas, to hold the next annual meeting there.

8. An invitation from W. G. Skelly, president of the Skelly Oil Company, Tulsa, Oklahoma, to attend the International Petroleum Exposition, May 18–25, was read by the president.

9. *Introduction of new officers.*—The newly elected officers of the Association were introduced by retiring president Henry A. Ley.

10. The twenty-fifth annual meeting adjourned at 10:30 A.M.

HENRY A. LEY, *president* ED. W. OWEN, *secretary*

EXHIBIT I. PRESIDENTIAL REPORT

(The Administration Ending April 12, 1940)

Another administration in the history of this Association comes to a close, and with it the first quarter century of the Association. We need not review the accomplishments of those two decades and five years. They are indestructibly carried in the publications of the Association and the spirit of the membership. A president's year is an educational year, out of which at least a few crystal-clear ideas should slowly evolve. The report that follows briefly covers certain of our activities and sets forth a few personal impressions and convictions.

Bulletin

We achieve integration through our *Bulletin*. It is the one activity of this Association that reaches to all corners of this earth and to all our members. We are not measured by membership numbers. The Association yardstick is its *Bulletin*. Through it we all meet on common ground.

The *Bulletin* is our most flexible cost item. Its size, and consequently the operating expenses of this Association, can be increased or reduced at the will of the Executive Committee according to the financial condition of the Association. This administration has striven to give the individual member the greatest possible value for his membership dollar by steadily increasing monthly text pages of the *Bulletin*. So far as compatible with current financial conditions of the Association, we believe the *Bulletin* should absorb most of our annual income.

There have been times heretofore when there was much uncertainty concerning a sufficiency of manuscripts for the *Bulletin*. We have, now, a substantial back-log of manuscripts. We believe that aggressive publication committees together with Executive Committees can insure a steady flow of material for publication in the *Bulletin*. We have found, this year, that our members individually and as local groups will prepare papers and will enthusiastically sponsor special volumes. The growth and scope of geologic thought is clearly cast and evident with even a casual chronologic survey of our publications.

Special Publications

In our revolving publication fund about $19,000 is available for new projects. It was not the intent of those who conceived and set up this fund that it should grow in size and then bog down in static lethargy. We have it for a very definite purpose—the conception, preparation, and publication of special volumes which further our knowledge of petroleum geology. Through the subsidy of these funds twelve special volumes have been published, of which seven are out of print. Revolving publication funds have been wisely used in the past. Two special volumes are now under way, and the groundwork for a third special volume has been laid. They are the following.

The Permian Volume, under the editorship of Ronald K. DeFord and the associate editorship of Professor Raymond C. Moore. Several more years may be required to gather and digest the material which the editors are obtaining in coöperation with many Association members.

Stratigraphic Traps, sponsored by our Research Committee under the immediate direction of A. I. Levorsen. This volume is well under way, and, I believe, will be ready for publication before the Permian volume.

The Appalachian Volume, sponsored by the Appalachian Geological Society has been approved by the Executive Committee.

All three volumes, just described, will present material not published previously. Each will treat its field in comprehensive fashion, and each is destined to become a milepost in the publication advancement of this Association.

Potential Volumes.—Future executive committees and the trustees of the Revolving Publication Fund must at all times concern themselves critically with potential, new material, new fields, and new subjects in petroleum geology and prospecting which this Association properly should sponsor and underwrite as special publications. There are certain fields and activities that lie wholly within our domain. Those, this Association should recognize early and pre-empt for ourselves.

For example, members have proposed that the Association sponsor and underwrite the following volumes.

1. The occurrence of oil in the stratigraphic column throughout North America.
2. A handbook or desk manual for geologists sufficiently comprehensive that a man finding himself lost in central Africa could have within one book all that a geologist or engineer might ever have occasion to use. The chemists, physicists, and mining engineers have their handbooks.
3. A comprehensive volume fully covering the subject of petroleum prospecting. Properly edited and adequately treated such a volume has a wide sales field among commercial geologists and students taking geology as a major. If this volume is ever prepared, provisions should be made for periodic revisions and the addition of new material.
4. A glossary of geological terms and terms related to the petroleum and natural gas industry.

Office in the Association

Here I want to emphasize that elevation of a member to the Executive Committee or to a standing committee of the Association, while it is a signal honor, can not be wholly so regarded by that fortunate member. Such honors, I believe, are membership expressions of confidence in leadership, the ability to develop new ideas, and a faith that men so honored will give their time as required to the welfare of the Association. Some of our past presidents have actually poured their very life blood into our organization to a degree that their normal life-span was cut short.

Membership

As of December 31, 1939, there were 3,213 members. On January 1, 1940, we dropped 49 members for 2-year delinquency. As of March 31, 1940, there were 3,261 members, consisting of 2,500 active and 761 associate—a net gain of 97 members in the first quarter of this year. There has been a steady rate of membership growth since 1935. There are no storm clouds on the horizon. Barring a national economic catastrophe, we shall continue to set new all-time membership records through the next decade. Our rate of annual growth may not be maintained. Yet we may anticipate a membership of approximately 4,000 within the next five years. To-day, including 99 non-member applicants approved by the Executive Committee and 75 non-member applicants not yet sent to the Executive Committee, we have a potential membership of 3,435 men.

Employment

Like the national economy we had our unemployment troubles. Our membership, you will recall, declined from a record high of 2,562 in 1931 to 1,973 members in 1935. But, unlike the national economy, membership and employment have steadily improved since 1935, setting all-time records annually thereafter. This record deserves mention. I attribute it to the achievement-motivated policies of the petroleum industry. That industry is a dynamic enterprise, retaining the spirit and action of pre-Civil war American pioneers. Static philosophies of government, business, and management seek only to preserve termite-ridden structures. Failure and collapse are the inevitable consequences of static philosophies. No one can forecast what may happen to any one of us as an individual, but, I believe, we can safely predict that as a

group and as an Association we shall continue to find employment within the petroleum industry.

Association Committees

All standing Association committees now carry constitutional authority. All are now organized so that one third of their roster must be replaced annually with new members. It is your president's opinion that chairmen, when selected and appointed, should be given complete freedom to carry on the activities of their committees.

Local Societies

There are three sections of the American Association of Petroleum Geologists, and twenty affiliated local geological societies. An additional local society will become affiliated during this meeting. I regard these as the backbone of the Association. They develop many ideas, some which the Association may sometimes use. Many of their ideas we may officially sponsor, encourage, or further. Our interests are mutual. Both can make lasting impressions on the pattern of geologic thought.

Activities of Local Societies

The national Association and the local geological societies have many interests and activities. Some lie on common ground. Those that do should be vigorously pursued for the common good of all.

Organized field trips are among the oldest activities sponsored by local societies. To advertise widely these trips among the national membership, the Executive Committee has authorized a separate Field-Trip page in the *Bulletin.* Greater efforts should be made to impress the management of the oil companies with the importance and values to be derived from organized field trips, both to the company and the employee.

Study-group activities within local societies deserve mention. The idea was initiated, I believe, by the Houston Geological Society. Many societies have adopted similar study-group plans. Some reports of the Houston society have appeared in the *Bulletin.* Study-group reports of other societies can be published in the *Bulletin.*

Student Awards, initiated by the West Texas Geological Society, deserve mention here. Not only does the future of this Association rest upon a prosperous petroleum industry, it also rests upon our younger members. The Student Award idea focuses the student's attention on this Association while still in halls of learning. We shall, undoubtedly, benefit from this constructive idea of a local society.

University Geological Departments, This Association, and the Oil Industry

There is another field with which, I believe, we should concern ourselves. It is one that would return its costs many fold to the petroleum industry. The petroleum industry should, I think, find ways and means whereby certain personnel of university geological departments can be brought into direct contact with practical geology.

It should be possible for such men to spend one or more months during their summer vacations as observers with pay in the geological, geophysical,

and paleontological departments of oil companies. They could thereby gain first-hand knowledge of the scope and nature of the problems faced by the industry; current trends of geological activity and techniques; and a better knowledge of what the industry wants in the graduates. Such a policy should result in better prepared graduates, more inspirational teaching, and a greater confidence of the student in his professor.

College and University Curricula

As civilization and business advance there are constant adjustments of education to reality. The establishment of schools merely provides educational facilities. Once buildings, equipment, and staff members are adequately provided, increasing emphasis must be placed upon curricula. Graduation and a degree do not lead to the immediate or even eventual realization of worthy dreams. Often they do not even prepare the graduate for even the most elementary positions in a profession or trade. Geology in the business world, we find, is becoming increasingly diversified. Curricula should be constantly adjusted to prepare youth for any of the diversified fields, once he has been grounded in fundamentals. Standardized programs are not, in my opinion, the way to better opportunities and a better life. To the end that we of this Association may convey our experiences to the academic world, I proposed a committee empowered to make a curricula survey. The Executive Committee approved the survey, and the committee has been appointed. The report of that committee will be published in the *Bulletin* and placed before educators in the geological departments of our universities and colleges. The committee will take whatever time is needed to make the survey and prepare their report, even though two or three years may be required.

Presidential Convictions

Our name carries the prefix "American." A few members periodically suggest that we delete "American." They tell us that the Association is a world-wide institution, and our prefix consequently a misnomer. I am an American by birth. Personally I disapprove efforts to delete the word "American." "American" is a broad inclusive term, equally applicable throughout this western hemisphere. Such requests have never come, to my knowledge, from continental Europe.

Some men believe that the scope of Association membership should be greatly expanded. They would qualify men engaged in pure business and trading aspects of the petroleum industry for membership. I have seen no need of such consolidation. It is my opinion that all organizations prosper most when each has the greatest freedom of expression and action. I do believe, however, that close working relationships with certain other organizations can benefit all of us.

Current Policies

This administration has placed emphasis upon the interdependence of geology and business enterprise, which together comprise the national petroleum industry. All of us have regarded our offices as strictly administrative, concerned with fostering the welfare of the Association and furthering the applications of geology in a practical sense. Business matters of the Association have been expedited by having the president and the secretary-treasurer

in the same town. A sincere spirit of coöperation prevailed throughout our term in office. We of this administration leave office with pleasant memories to enliven the gray-beard years that lie ahead of us.

HENRY A. LEY, *president*

EXHIBIT II. REPORT OF SECRETARY-TREASURER
(Year Ending April 12, 1940)

MEMBERSHIP

Membership in the Association continued to increase during the year, reaching a new high of 3,240 on March 1, 1940. The net increase during the year was 289 or approximately 10 per cent. New applications are continuing at about the same rate. There is a notable tendency for an increased diversification in the activities of our members, which will be apparent in the results of the occupational survey which has been conducted by the executive committee, an analysis of which will be published in an early *Bulletin*. We are now receiving numerous applications for membership from men who are trained geologists but whose work consists largely of the application of geology to petroleum engineering and production problems. We are also receiving an increased number of applications from advanced students of geology in the various universities, who are joining the Association at the very beginning of their professional careers. The thorough training and high quality which characterizes most of these new applicants make their admission very desirable, and it is our opinion that the Association should continue to encourage these groups of men to assume their proper share in our activities.

During the past year we have been unfortunate in the loss of several of our most valuable members, three of whom were past-presidents of the Association. Members whose deaths occurred during the year were:

Donald C. Barton (past-president)
I. M. Goubkin
George A. Kroenlein
George C. Matson (past-president)
H. A. Nedom
F. S. Prout
Ralph D. Reed (honorary member and past-president)
Walter W. Scott
W. A. Tarr

Tables I, II, and III furnish comparative data on membership by years and geographic distribution. The percentage of associates in the total membership has increased slightly during the year and promises to continue to do so for some time. However, there are now many associates who are qualified for active membership and who should be encouraged to change their status and take a more active part in Association affairs. There has been very little modification in our geographic distribution.

FINANCES

The usual annual audit was published in the March, 1940, *Bulletin*. Tables IV to IX inclusive furnish additional information and comparative figures as to our financial record for the past few years. It will be noted that

the year 1939 showed a larger net profit than has been the case for several years. This was due in considerable part to certain unusual items of income, such as the special sale of out-of-date publications and an unusually large sale of special publications. According to the budget, which has been prepared and which appears in Table X, no profit of such magnitude is to be expected during the current year.

Due to the increased membership and the consequent increase in distribution of the *Bulletin* there has been an additional decline in the publishing cost per copy, in spite of the fact that the number of text pages has been increased. Table VIII presents the pertinent data as to costs for the past three years. In the budget for 1940, provision is made for a further increase in size and quality of the *Bulletin.*

The rate of return which the Association was able to obtain on many of its investments continued to decline during 1939. It has been the studied opinion of the executive and finance committees that the surplus of the Association should be maintained in as liquid condition as possible, and that the safety of these funds is a far more important consideration than the income to be derived from them. In view of the high market value of sound income-bearing securities it is felt that few security purchases should be made at the present time. Consequently, our cash position has been increased and a considerable amount is being carried in savings accounts and Government savings bonds bearing a low rate of interest. These funds will be available for the purchase of high-grade securities at such time as their market position may offer more attractive possibilities for investment. On April 1, 1940, our investment account stood as follows:

Bonds	$28,461.03
Preferred stocks	3,858.24
Common stocks	26,456.16
Morris Plan	4,223.11
Savings accounts	15,004.16
	$78,002.70

EXECUTIVE COMMITTEE MEETINGS

The executive committee met during our conventions at Oklahoma City and at Chicago and had an additional meeting in Tulsa on September 16 and 17. Throughout the entire year the officers have been in constant contact with each other through correspondence, and all actions of the executive committee have been made by unanimous vote.

ACKNOWLEDGMENTS

The secretary-treasurer wishes to express his appreciation for the wholehearted coöperation which he has received from the other members of the executive committee, from the finance committee and from the trustees of the research and publication funds. It seems proper to call to the attention of the Association the fact that our headquarters office has carried on efficiently an enormous amount of work, the size and importance of which can not be appreciated except by those in close contact with this office. The loyal coöperation which the headquarters staff has given to your executive committee has been the basis for whatever we have been able to accomplish.

ED. W. OWEN, *secretary-treasurer*

TABLE I

Total Membership by Years

May 19, 1917	94	March 1, 1929	2,126
February 15, 1918	176	March 1, 1930	2,292
March 15, 1919	348	March 1, 1931	2,562
March 18, 1920	543	March 1, 1932	2,558
March 15, 1921	621	March 1, 1933	2,336
March 8, 1922	767	March 1, 1934	2,043
March 20, 1923	901	March 1, 1935	1,973
March 20, 1924	1,080	March 1, 1936	2,169
March 21, 1925	1,253	March 1, 1937	2,331
March 20, 1926	1,504	March 1, 1938	2,646
March 1, 1927	1,670	March 1, 1939	2,951
March 1, 1928	1,952	March 1, 1940	3,240

TABLE II

Comparative Data of Membership

	March 1, 1939		*March 1, 1940*	
Number of honorary members	16		16	
Number of life members	3		4	
Number of members	2,287		2,461	
Number of associates	645		759	
Total number of members and associates		2,951		3,240
Increase in membership		305		289
Members and associates	334		316	
Reinstatements	53		40	
Total new members and reinstatements		387		356
Applicants elected, dues unpaid	27		16	
Applicants approved for publication	55		45	
Recent applications	78		77	
Total applications on hand		160		138
	March 1, 1939		*March 1, 1940*	
Applicants for reinstatement, elected, dues unpaid	8		5	
Recent applications for reinstatement	3		1	
Total applications for reinstatement on hand		11		6
Applicants approved for transfer, dues unpaid	28		9	
Applicants for transfer approved for publication	14		40	
Recent applications for transfer on hand	37		9	
Total applications for transfer on hand		79		58
Number of members and associates resigned	11		7	
Number of members and associates dropped	60		51	
Number of members died	11		9	
Total loss in membership		82		67
Total gain in membership		305		289
Number of members and associates in arrears, previous year	80		116	
Members in arrears, current year	766		808	
Associates in arrears, current year	215		249	
Total number members and associates in arrears current year		981		1,057
Total number members and associates in good standing		1,890		2,067

TABLE III

Geographic Distribution of Members

March 1, 1940

Alabama	5	Louisiana	154	Oklahoma	447
Arizona	1	Maine	2	Oregon	1
Arkansas	17	Maryland	3	Pennsylvania	61
California	399	Massachusetts	8	South Dakota	4
Colorado	43	Michigan	29	Tennessee	5
Connecticut	6	Minnesota	4	Texas	1,085
Delaware	1	Mississippi	34	Utah	3
Dist. of Columbia	37	Missouri	25	Vermont	1
Florida	4	Montana	9	Virginia	2
Georgia	1	Nebraska	8	Washington	5
Illinois	95	New Jersey	8	West Virginia	20
Indiana	45	New Mexico	24	Wisconsin	2
Iowa	5	New York	81	Wyoming	17
Kansas	126	N. Carolina	4		
Kentucky	19	Ohio	20		

Total members in United States 2,870

Alberta	16	Ecuador	3	Ontario	4
Angola	1	Egypt	12	Palestine	2
Arabia	1	England	19	Papua	7
Argentina	15	France	5	Persian Gulf	7
Australia	9	Germany	8	Peru	3
Austria	1	Guatemala	1	Philippine Is.	6
Barbados	1	Haiti	1	Poland	3
Belgian Congo	1	Hawaii	1	Roumania	7
Belgium	1	Hungary	1	Scotland	2
Borneo	1	India	7	Sumatra	13
Brazil	1	Iran	1	Switzerland	9
British Columbia	1	Iraq	6	Syria	4
Burma	1	Italy	3	Trinidad	8
Canal Zone	1	Japan	3	Turkey	3
Colombia	37	Java	4	Uganda	1
Cuba	6	Madagascar	1	Union So. Africa	1
Cyprus	1	Mexico	8	Uruguay	1
Denmark	3	Netherlands	20	Venezuela	71
Dominican Republic	2	New Guinea	2		
Dutch Guiana	1	New Zealand	11		

Total members in foreign countries 370
Grand total 3,240

TABLE IV

Comparison of Accrued Income by Calendar Years

	1937	*1938*	*1939*
Dues			
Members	$19,880.00	$22,170.00	$24,640.00
Associates	3,546.00	4,408.00	4,756.00
Total	$23,426.00	$26,578.00	$29,396.00
Bulletin			
Subscriptions	$ 4,531.94	$ 4,376.96	$ 4,645.43
Advertising	7,084.95	7,093.72	8,651.75
Total	$11,616.89	$11,470.68	$13,297.18
Back Numbers, etc.			
Bound Volumes of Bulletin	$ 2,911.60	$ 2,533.93	$ 3,044.70
Back Numbers of Bulletin	1,136.97	858.10	1,284.93
Other Publications	170.70	66.34	74.88
Total	$ 4,219.27	$ 3,458.37	$ 4,404.51

Special Publications	*1937*	*1938*	*1939*
Structure Volume I*	$ 135.30	$ —	$ —
Structure Volume II	617.05	439.52	884.20
Geology of California*	196.24	—	—
Problems of Petroleum Geology	1,023.80	639.88	—
Geology of Natural Gas*	917.14	616.38	675.60
Geology of Tampico Region*	667.46	172.67	158.98
Index	448.36	115.04	55.62
Gulf Coast*	4,197.86	743.44	640.08
Struct. Evol. Sou. California*	1,117.13	299.44	229.24
Tectonic Map*	107.87	21.90	21.45
Miocene Stratigraphy of California*	—	368.00	1,972.90
Recent Marine Sediments*	—	—	2,993.20
Total	$ 9,428.21	$ 3,416.27	$ 7,631.27
Other Income			
Convention Receipts (Net)	$ —	$ —	$ 808.66
Delinquent Dues Charged Off	544.00	118.00	297.00
Interest	2,074.47	1,901.26	1,718.98
[1]	65.63	74.14	80.72
*	501.78	437.66	387.45
Miscellaneous	29.47	83.33	157.20
Sale of Library	56.50	—	25.50
Members Reinstated	210.10	144.77	81.00
Bad Debt, Back Interest, Recovered	160.00	—	—
Inventory Increase	1,313.87	733.38	—
Contributions[1]	—	300.00	—
Adjustment of stated value of Investments to lower of cost or market	—	—	472.97
Total	$53,646.19	$48,715.86	$58,758.44

* Income of Publication Fund.
[1] Income of Research Fund.

TABLE V

Comparison of Accrued Expenses by Years

General and Administrative Expenses	*1937*	*1938*	*1939*
Salaries—Manager	$ 2,782.70	$ 2,840.00	$ 3,225.00
Clerical	5,675.69	5,762.62	5,543.10
Rent	1,460.00	1,500.00	1,500.00
Telephone and Telegraph	444.58	249.51	342.54
Postage	1,315.62	1,675.30	1,394.92
Office Supplies and Expenses	501.51	448.73	354.76
Printing and Stationery	440.16	408.05	321.91
Audit Expense	300.00	300.00	150.00
Insurance and Taxes	155.14	179.28	186.64
Convention Expense (Net)	388.25	80.84	—
Freight and Express (Shipments from Tulsa)	254.17	128.03	161.01
Bad Debts	—	408.76	750.07
Donations—Soc. Econ. Pal. & Min.	500.00	—	—
Soc. Econ. Geol.	250.00	—	—
Miscellaneous	253.76	360.29	173.05
Depreciation—Furn. and Fixtures	393.39	388.03	399.00
Investment Counsel	400.00	400.00	400.00
Loss on sale of Bonds, etc. (Net)	4.31	1,491.24	252.25
Excess of cost of Investments over lower of Cost or Market	—	5,718.43	—
Bass-Neumann Research Project	—	—	416.94
Van Tuyl-Parker Research Project	—	—	100.00
Tectonic Map of United States	—	—	300.00
	$15,519.08	$22,339.11	$15,953.19

Less Expenses charged Soc. of Econ. Paleon. and Mineralogists	—	702.81	—
Total	$15,519.08	$21,636.30	$15,953.19
Publication Expenses	*1937*	*1938*	*1939*
Salaries—Manager	$ 2,925.00	$ 3,000.00	$ 3,562.50
Editorial	3,495.22	4,840.00	3,950.00
Printing Bulletin	12,144.88	12,778.54	15,274.68
Engravings	1,695.20	1,945.66	2,271.29
Separates	246.59	149.04	151.31
Stencils and Mailing	184.36	229.54	230.19
Binding Bulletins	409.04	491.10	623.55
Postage and Express (Bulletins)	887.76	962.08	1,180.04
Copyright Fees	24.00	24.00	24.00
Freight, Express, Postage (Other Publications) Shipments from Printers	1,343.55	460.02	240.76
Discounts	51.97	13.53	40.92
Purchase of Back Numbers	—	—	18.00
Bad Debts	269.31	7.19	67.33
Miscellaneous	169.48	10.59	20.88
Special Publications	9,799.47	4,134.86	4,200.03
Bulletin Inventory Decrease	—	—	1,676.22
Special Publication Inventory Decrease	—	—	443.96
Total	$33,645.83	$29,046.15	$33,975.66
Total Expense	$49,164.91	$50,682.45	$49,928.85

TABLE VI

Comparison of Net Income by Years

	1937	*1938*	*1939*
Accrued Income	$53,646.19	$48,715.86	$58,758.44
Expenses			
General and Administrative	15,788.39	21,636.30	15,953.19
Publication	33,376.52	29,046.15	33,975.66
Total	$49,164.91	$50,682.45	$49,928.85
Excess Income over Expenses	$ 4,481.28	$ 1,966.59	$ 8,829.59

TABLE VII

Investments

	Cost	*Market Value End of Year*
1937 Values		
General Fund	$44,431.55	$38,288.12
Publication Fund	12,712.46	11,397.84
Research Fund	1,545.57	1,449.93
Total	$58,689.58	$51,135.89
1938 Values		
General Fund	$49,438.27	$45,485.20
Publication Fund	11,843.40	11,634.90
Research Fund	1,896.05	1,738.55
Total	$63,177.72	$58,858.65
1939 Values		
General Fund	$58,341.06	$56,281.51
Publication Fund	12,412.50	12,090.87
Research Fund	2,249.14	2,072.89
Total	$73,002.70	$70,445.27

TABLE VIII

COMPARISON OF COST OF BULLETIN

	1937	*1938*	*1939*
Total Expenses	$21,663.21	$23,939.45	$26,655.96
Monthly Edition	3,500	3,900	4,400
Total Copies Printed	42,000	46,800	52,800
Total Pages Printed, Including Covers	2,061	2,174	2,374
Total Pages of Text	1,641	1,746	1,922
Total Cost Per Copy	0.515	0.512	0.505

TABLE IX

(Section 1)

SPECIAL PUBLICATIONS

	Structure Vol. II	*Problems Petroleum Geology*	*Geology Natural Gas*	*Geology Tampico Region*	*Gulf Coast Oil Fields*	*Total*
Inventory						
Dec. 31, 1938	$ 655.20	$ 14.75	$2,964.00	$1,873.22	$1,649.70	$7,156.87
Dec. 31, 1939	79.20	—	2,376.00	1,772.46	1,272.37	5,500.03
Sales	884.20	—	675.60	158.98	640.08	2,358.86
Total Edition	2,500	2,034	2,500	1,575	2,510	—
Copies on Hand						
Dec. 31, 1938	182	5	741	818	940	
Dec. 31, 1939	22	0	594	774	725	
Number of Pages	780	1,073	1,227	280	1,070	
Cost (inventory) per Copy	$3.60	$2.95	$4.00	$2.29	$1.755	
Selling Price, when issued, per Copy	4.00	5.00	4.50	3.50	4.00	
Present Selling Price						
Members and Associates	8.00	—	4.50	3.50	3.00	
Non-Members	8.00	—	6.00	4.50	4.00	

TABLE IX

(Section 2)

SPECIAL PUBLICATIONS

	Comprehensive Index (Paper)	*Struc. Evolution Southern California*	*Tectonic Map of Southern California*	*Miocene Stratig. of California*	*Recent Marine Sediments*	*Total*
Inventory						
Dec. 31, 1938	$1,513.92	$ 214.73	$ 53.12	$3,450.15	$ —	$5,231.92
Dec. 31, 1939	861.54	67.58	49.28	2,346.30	1,943.20	5,267.90
Sales	55.62	229.24	21.45	1,972.90	2,993.20	5,272.41
Total Edition	1,271	1,047	940	1,530	1,500	
Copies on Hand						
Dec. 31, 1938	912	197	664	1,394	—	
Dec. 31, 1939	519	62	616	948	694	
Number of Pages	382	157	—	450	736	
Cost (inventory) per Copy	$1.66	$1.09	$0.08	$2.475	$2.80	
Selling Price, when issued, per Copy—Members, Associates		2.00	.50	4.50	4.00	
Non-Members	—	2.00	.50	5.00	5.00	
Present Selling Price						
Members and Associates	2.00	2.00	.50	4.50	4.00	
Non-Members	3.00	2.00	.50	5.00	5.00	

TABLE X
BUDGET

Revenues	*1937*	*1938*	*1939*	*1940*
Dues	$23,426.00	$26,578.00	$29,396.00	$31,000.00
Bulletin				
Subscriptions	4,531.94	4,376.96	4,645.43	4,000.00
Advertising	7,084.95	7,093.72	8,651.75	8,000.00
Bound Volumes	2,911.60	2,533.93	3,044.70	3,300.00
Back Numbers	1,136.97	858.10	1,284.93	2,000.00
Special Publications				
Structure Vol. I	1,355.34	639.88	—	—
Structure Vol. II	617.05	439.52	884.20	75.00
Geology of Natural Gas	917.14	616.38	675.60	600.00
Geology of Tampico Region, Mexico	667.46	172.67	158.98	150.00
Comprehensive Index	448.36	115.04	55.62	30.00
Gulf Coast Oil Fields	4,197.86	743.44	640.08	600.00
Struc. Evol. Southern California and map	1,117.13	299.44	229.24	100.00
Miocene Stratigraphy of California	—	368.00	1,972.90	600.00
Recent Marine Sediments	—	—	2,993.20	1,500.00
Other	278.57	88.24	96.33	300.00
Other Income				
Miscellaneous	760.50	346.10	1,369.36	500.00
Investments	2,641.88	2,413.06	2,187.15	2,000.00
Total	$52,092.75	$49,682.48	$58,285.47	$54,755.00
Expenses				
General	$15,395.83	$14,366.51	$14,960.26	$16.000.00
Publication	24,689.90	24,890.57	27,579.19	35,575.00
Research	—	—	816.94	2,500.00
Loss of Sale of Investments	—	—	252.25	250.00
Special Volumes	8,686.62	4,134.86	4,200.03	—
Travel Exp. Exec. Com.	—	—	—	1,000.00
Total	$48,772.35	$43,391.94	$47,808.67	$55,325.00

EXHIBIT III. REPORT OF THE EDITOR

The year 1940 marks the 25th anniversary of the Association. It also brings to a close the third year of service of the present editor. Although three years is a relatively short span of time, it nevertheless is a sufficiently long period to furnish a basis for statistical comparisons.

When the present editor began to examine manuscripts in March, 1937, he found that certain methods of procedure had been developed by his predecessors which permitted the work of the editorial staff to function smoothly. Therefore, no important changes were instituted. The large group of faithful associate editors was asked to continue to serve as before and the list at the close of the third year is nearly the same as it was at the beginning of the triennium. The guiding principle of this group of workers has been to provide the greatest amount of entertaining and instructive reading for the greatest number of our members. That this ideal was approximated is indicated by the many letters received which express satisfaction with our selection of material and the few letters of criticism.

The editor began almost immediately to collect statistics regarding the source of the papers which finally appear in the *Bulletin* and also the affiliations of the contributors. These statistics furnish some interesting sidelights on the forces which operate to supply a group of ravenous readers with material for intellectual enjoyment. Furthermore they may serve to guide future editors to make their work more effective and lead them to concentrate on certain lines of approach. Therefore, the statistics covering three years are here presented.

In Table I the number of articles printed in the *Bulletin* each year (beginning with the April number and ending with the March number of the succeeding year) are shown. These articles are generally classified for convenience as Majors and Minors. They include all long articles published in the *Bulletin* and all Geological Notes. They do not include such items as appear under the head of Reviews, Discussion, the Association Round Table, or New Publications. In other words they are the papers which contain some new geological data of interest to our readers.

TABLE I. SOURCE OF BULLETIN PAPERS

Year	*Number of Papers*	*Conventions*	*Spontaneous*	*Publication Committee*	*Editor*
1937	83	34	39	7	1
1938	92	49	27	11	5
1939	108	48	28	15	17

From this table it will be apparent that most of our papers come from the programs of our conventions. Some of these are read at the time of the convention and others are listed as read by title. The annual convention supplies the greatest number of papers. During the fall of 1937 there was a mid-year convention in Pittsburgh, Pennsylvania. This convention helped to supply papers for the ensuing year. During the fall of 1938 there was a convention in El Paso, Texas. This convention also helped to supply a considerable number of papers which did not begin to appear until January, 1940, and which will continue to appear during 1940.

The second most fruitful source of papers is called the spontaneous group and includes all papers sent in by the respective authors without any coaxing by members of the Publication Committee or the editor. It will be well to recall that the Publication Committee began to function during the year 1937 and did not get its full momentum until the following year. It should also be pointed out that the number of papers that should be credited to the efforts of this committee is considerably larger than the figure shown in the table. The reason for this discrepancy is the fact that members of the committee secure many major papers which are presented at the time of the next convention. Up to the present the work of this committee has produced a gratifying increase in the number of Geological Notes. It is also apparent that it is quite impossible to secure enough papers of high quality without the aid of this committee.

An interesting sidelight on publication results is provided by a comparison of the number of papers appearing on the annual convention programs and the proportion later published. For instance, the New Orleans (1938) program listed 99 papers of which about half, or 51, were later published. The Oklahoma City program contained 70 papers of which exactly half were submitted and later published. The editor finds that the papers listed on such a

program are apt to come to his desk rather promptly and that most of those which are eventually published are available for publication within five months after the convention. This means that we have a large supply of papers during the first half of our year and must fall back on the spontaneous group during the latter half of the year. An important exception, of course, is provided when we have a mid-year meeting.

When a paper reaches the editor's desk it is carefully read and appraised. It is then turned over to at least two other members of the Association for critical reading. In addition to the associate editor several other persons who are particularly well acquainted with the subject matter of the paper are consulted. Then the paper is returned to the author with the suggestions of the various readers and he is given an opportunity to make the changes suggested. The paper is then prepared for publication by our editorial staff in Tulsa. Necessary changes in diction and spelling are incorporated. Also at this time a careful check of the use of geologic names is made both for spelling and for stratigraphic correctness. In case of doubt the paper is submitted to a member of the Geologic Names and Correlations Committee for critical revision. The whole process of critical reading and preparation for printing takes about two months, or longer.

TABLE II. PROFESSIONAL SOURCE OF PAPERS

Year	*Number of Papers*	*Oil-Company Men*	*Consulting Men*	*Teachers*	*State Surveys*	*Federal Surveys*
1937	83	45	14	13	6	6
1938	92	41	16	16	9	9
1939	108	53	15	21	11	8

Table II shows the professional connections of authors of papers published in the *Bulletin*. It will be noted that approximately half of the papers originate in the offices of oil companies. Approximately 15 per cent of the papers are written by geologists who are not directly connected with any major company but who are doing consulting work. A very similar proportion of papers is written by geologists who are teaching or doing research work in universities. The various State geological surveys, bureaus, and similar agencies account for nearly 10 per cent of the papers while a slightly smaller percentage originates in the Federal surveys. The last category includes the United States Geological Survey, the Canadian Survey, and similar organizations in other parts of the world.

Despite the gratifying showing made by the statistics which indicate that the number of papers has increased from 83 to 108 and that the number of pages has increased steadily during the last three years so that during the early months of 1940 it is averaging about 200 for each issue, a note of warning is in order. The *Bulletin* still needs more papers. Please let me remind you that this is your *Bulletin* and that we would like to have you send in a contribution. It need not be lengthy nor must it be a scholarly dissertation. In fact we welcome especially the type of contribution which can be published as a short geological note and which presents interesting details about a new discovery of geological import. Logs of extra-deep holes, or of test wells which penetrate new and hitherto untested formations, are especially wanted. This type of information is most valuable and interesting when it is fresh. We never seem to get enough material for our Geological Notes section. During the last

year the Executive Committee has authorized the publication of four special publications. A Permian volume, an Oil Field volume, a Memorial volume and a book on the Appalachian region. These will appear in print within the next three or four years. These are more fully discussed in the president's report.

In conclusion four additional tables are presented which bring the statistical data up to date and permit comparisons with previous years.

TABLE III. GEOGRAPHIC DISTRIBUTION OF MAJOR ARTICLES AND GEOLOGICAL NOTES

Texas	30	Montana	4
General	14	Kentucky	4
New Mexico	9	Colorado	3
Louisiana	8	Utah	3
Oklahoma	7	Arkansas	2
Kansas	7	Florida	2
California	6	Nebraska	2
Illinois	6	Ohio	2
Wyoming	5		

One article for each of the following: Alabama, West Virginia, Indiana, Mississippi, Missouri, South Dakota, Peru, Russia, Trinidad, Turkey, Sumatra.

TABLE IV. BULLETIN PAGES BY MONTHS

	Majors		*Minors*		*Majors and Minors*		*Advertising and Misc.*		*Total*	
	'38	*'39*	*'38*	*'39*	*'38*	*'39*	*'38*	*'39*	*'38*	*'39*
Jan.	99	100	29	20	128	120	28	32	156	152
Feb.	88	125	24	35	112	160	32	32	144	192
Mar.	65	58	87	122	152	180	28	32	180	212
Apr.	97	141	24	23	124	164	32	28	156	192
May	57	61	59	79	116	140	32	32	148	172
June	130	203	26	15	156	218	32	36	188	254
July	126	85	38	63	164	148	28	32	192	180
Aug.	148	97	32	59	180	156	28	28	208	184
Sept.	139	117	33	35	172	152	32	32	204	184
Oct.	142	121	26	43	168	164	32	32	200	196
Nov.	127	109	29	39	156	148	28	32	184	180
Dec.	58	84	60	88	118	172	48	56	166	228
Total	1,276	1,301	470	621	1,746	1,922	380	404	2,126	2,326
Monthly Average	106.3	108.3	39.1	51.7	145.5	160.1	31.6	33.6	177.1	193.8

TABLE V. PAPERS FROM ANNUAL MEETINGS

Papers on New Orleans program (1938)	99
Papers submitted and published	51
Papers on Oklahoma City program (1939)	70
Papers submitted	35
Papers published	34

TABLE VI. TOTAL BULLETIN PAGES AND CONTENTS BY YEARS

	1936	*1937*	*1938*	*1939*
Pages of major articles	1,300	1,191	1,276	1,301
Pages of minor articles	422	450	470	621
Pages of majors and minors	1,722	1,641	1,746	1,922
Pages of advertising, etc.	308	372	380	404
Total pages	2,046	2,013	2,126	2,236
Number of illustrations	372	388	378	470
Number of major articles	61	70	70	60
Number of minor articles*	74	83	70	92

* Minor articles: geological notes, study groups, discussions, reviews, memorials.

W. A. VER WIEBE, *editor*

EXHIBIT IV. REPORT (MINUTES) OF BUSINESS COMMITTEE
Stevens Hotel, Chicago, Illinois, April 9, 1940

The meeting was called to order at 10:15 A.M. by L. C. Morgan, chairman. The following members were present.

Vice-chairman: E. O. Markham

Executive committee: Henry A. Ley, L. Murray Neumann, Ed. W. Owen, W. A. Ver Wiebe

Members-at-large: Paul L. Applin, A. R. Denison, J. V. Howell, Max L. Krueger, John N. Troxell

Division of Paleontology: H. B. Stenzel, Gayle Scott

District Representatives:

Amarillo: Carl C. Anderson represented by C. Don Hughes
Appalachian: Paul H. Price
Canada: S. E. Slipper
Capital: Arthur A. Baker
Dallas: P. W. McFarland
East Oklahoma: W. B. Wilson, N. W. Bass represented by Glenn D. Hawkins, Robert H. Wood represented by John G. Bartram
Fort Worth: Charles E. Yager
Great Lakes: William Norval Ballard, A. H. Bell
Houston: Wallace C. Thompson, J. Boyd Best represented by R.L. Beckelhymer, Lon D. Cartwright, Jr.
New Mexico: not represented
New York: W. T. Thom, Jr.
Pacific Coast: E. J. Bartosh, Harold K. Armstrong represented by Harold W. Hoots, H. L. Driver represented by R. G. Reese
Rocky Mountains: C. E. Dobbin
Shreveport: C. L. Moody
South America: not represented
Southeast Gulf: not represented
South Permian Basin: Ronald K. DeFord
South Texas: C. C. Miller and Harry H. Nowlan
Tyler: Edward B. Wilson represented by G. J. Loetterle
West Oklahoma: C. W. Tomlinson
Wichita: James I. Daniels represented by Phil K. Cochran
Wichita Falls: Virgil Pettigrew

1. *Minutes of previous meeting.*—It was moved, seconded, and carried that the reading of the minutes of the last meeting of the committee be omitted as the minutes had been published in the *Bulletin.*

2. *Report of constitutional committee,* W. B. Heroy, chairman. After the reading of the following report, it was moved, seconded, and carried that the report be accepted.

REPORT OF CONSTITUTIONAL COMMITTEE

Houston, Texas, April 1, 1940

To the Members:

From the responses received to my letter of March 2, 1940, it would appear that while most of the members of the committee feel that the majority of the Association would doubtless adjust themselves to any emergency, it would be better to have some specific constitutional provision to take care of vacancies arising in the executive committee.

The suggestions received may be summarized as follows:

1. Fill vacancy by unanimous vote of the executive committee
   A. By appointment of a past officer; or
   B. By appointment of any available person
      a. In case of deadlock, the next preceding past-president to cast the deciding vote; or
      b. In case of deadlock, the president to cast the deciding vote.
2. Fill all vacancies by appointment of the president or his successor;
3. Fill vacancy in the membership of the past-president by appointment of the immediately preceding past-president.

The purpose of having a past-president serve on the executive committee is to establish continuity of policy, and it would therefore appear to fit into the spirit of our constitution to have a vacancy in the executive committee, caused by the absence or disability of the past-president, filled by the next preceding past-president who might be available.

Vacancies in the offices of vice-president, secretary-treasurer, or editor should, according to the views of most of you, be filled by the executive committee. It would appear that there would be no objection to the president exercising the deciding vote in case of a tie.

In an endeavor to put these views in definite form, I have drafted the following proposed amendment of the constitution.

ARTICLE IV. OFFICERS AND THEIR DUTIES

SECTION 5. The vice-president shall assume the office of president in case of a vacancy from any cause in that office and shall assume the duties of president in case of the absence or disability of the latter. If the past-president shall for any reason be unable to serve as a member of the executive committee, the president shall fill the vacancy by the appointment of the next available preceding past-president.

A vacancy or disability occurring in the office of vice-president, secretary-treasurer, or editor shall be filled by majority vote of the executive committee, either for the unexpired term or for the period of disability, as the committee may decide. In the case of a tie, the president shall cast the deciding vote.

The business committee meets on Tuesday afternoon, April 9, and we have been requested to present a report at that time. I will therefore appreciate receiving immediately your reaction to this letter.

Yours very sincerely,
(Signed) WILLIAM B. HEROY, chairman
1405 2nd Natl. Bank Bldg.

Messrs. R. S. McFarland
Robert H. Wood
Earl B. Noble
Anthony Folger
W. C. Spooner
Ira H. Cram
cc Henry A. Ley

3. It was moved, seconded, and carried that the application of the Mississippi Geological Society to become affiliated with the Association be approved and recommended to the annual business meeting.

4. It was moved, seconded, and carried that action on the application of the Northeastern Ohio Geological Society to become affiliated with the Association be deferred until further investigation and study could be made by the officers of the Appalachian Geological Society and the executive committee.

5. Ways and means of consolidating the position and welfare of consulting and free-lance geologists who are members of the Association was discussed.

6. It was moved, seconded, and carried that the executive committee

may recognize the propriety of paying traveling expenses of the president or any other designated officer up to an amount not exceeding $1,000.00 per year and that it be arranged that each geographic section be visited by one member of the executive committee each year.

7. It was moved, seconded, and carried that the executive committee be requested to continue investigation of different types of group insurance for Association members and action be postponed until a later date.

8. It was moved, seconded, and carried that the report of the committee studying methods of electing officers be spread upon the records and the committee discharged with the thanks of the Association.

9. A resolution providing for the submission of a proposed constitutional amendment providing for a change in the method of electing officers was presented by W. B. Wilson.

(Recess for Lunch)

The meeting was called to order at 2:15 P.M. by L. C. Morgan, chairman.

A résumé of Mr. Wilson's proposal and the parliamentary status of the meeting was given by W. B. Heroy at the request of the chairman. A roll call vote on Mr. Wilson's resolution was then taken and the results of vote were as follows.

In favor	13
Opposed	16
Not Voting	13

10. Motion made by W. C. Thompson that the majority report of the committee studying methods of electing officers be accepted. Motion withdrawn by Thompson without a vote.

11. A motion was made by E. O. Markham and seconded that a committee be appointed by the present president to restudy nomination and election of officers and report to the business committee at the next session. J. V. Howell offered an amendment to Markham's motion, which was seconded, that this committee be instructed to formulate and present a method of electing officers by mail ballot and present this in such fashion that it can be brought to vote of the Association members. Motion and amendment were passed.

12. *Report of committee on applications of geology*, C. E. Dobbin, chairman, was not read but was recommended for publication in the *Bulletin*.

13. Confidential survey of membership income was recommended by Ronald K. DeFord, followed by general discussion during which a revision of the present code of ethics was suggested.

It was moved, seconded, and carried that the following reports be not read but recommended for publication in the *Bulletin*.

14. *Report of representative on Division of Geology and Geography, National Research Council*, Frederic H. Lahee, representative.

15. *Report of committee for publication*, R. E. Rettger, chairman.

16. *Report of geologic names and correlations committee*, John G. Bartram, chairman.

17. It was moved, seconded and carried that only the monetary projects of the *report of the research committee*, A. I. Levorsen, chairman, be read, and that the complete report be published in the *Bulletin*.

(1) Motion passed recommending the renewal of the grant of $1,000 to

the research committee to be a part of the research fund and used in promoting research in petroleum geology.

(2) Moved, seconded, and carried that it be recommended that a sum of $1,500 be made available to the Tulsa Geological Society for completion of a coöperative project covering the relation of oil analyses to stratigraphy.

(3) Moved, seconded, and carried that it be recommended that $300 be appropriated to the research committee for publication of a report by F. M. Van Tuyl and Ben H. Parker, "Time of Origin and Accumulation of Petroleum," such publication to be sold and proceeds therefrom to revert to the Association. Motion passed that the publication project be submitted to the trustees of the revolving publication fund. Motion made that the president be requested to appoint a committee to investigate the advisability and procedure of the publication of mimeographed copies of certain material for limited distribution and that such committee be composed of the three trustees of the revolving publication fund and four additional members

The president offered the information that several projects for the publication of special volumes are under way.

Meeting adjourned at 4:00 P.M.

L. C. MORGAN, *chairman* ED. W. OWEN, *secretary*

EXHIBIT V. REPORT OF COMMITTEE ON GEOLOGIC NAMES AND CORRELATIONS

The study of Permian nomenclature was the most important work of this committee in the last year. Previous discussion and differences of opinion led to the formation of a Permian sub-committee to prepare and publish a digest and recommendations. C. W. Tomlinson, chairman, John Emery Adams, M. G. Cheney, Robert H. Dott, and Raymond C. Moore comprised the sub-committee and did much work and wrote many letters to geologists with ideas or data concerning the problem. They considered the suggestion of the West Texas geologists that the Permian section of that area be considered a standard section for the United States. Their complete report, entitled "Classification of Permian Rocks" was published in the *Bulletin*, February, 1940, pages 337–58. They recommended that the Permian be recognized as constituting an independent geologic system, and described a standard section of four series in West Texas. They did not make correlations into other areas, but leave that for the local geologists who know their own sections best. It is expected that others working on the Permian will show the relation of their units to the members of the standard section, even though the mappable breaks may not come at the same places. This should aid regional correlations. The sub-committee's report contains a "Review of Stratigraphic Principles" which is a valuable addition to the literature on geologic nomenclature. With its assigned task completed and the report published, the sub-committee has been discharged with appreciation for their good work.

Since the original rules for "Classification and Nomenclature of Rock Units" were not readily available to younger authors, they were republished in the *Bulletin*, July, 1939, and a supply of separates provided for those needing them. It was provided that type sections of subsurface formations be filed with the United States Geological Survey in Washington and with the geological survey of the state in which they are located. It now develops that the United States Geological Survey has no proper facilities for filing such well samples and they need not be sent to Washington.

As usual, members of the committee read many papers and advised the editor and associate editors regarding the use of geologic names. The purpose of this work is to follow the accepted rules of nomenclature to prevent confusion, but not to dictate on the use of new names and correlations. An official committee should not state that one correlation or name is right and another wrong, since science is generally advanced by the individual or minority that has new ideas or does better work.

Because they have advanced the Permian from series to system rank, the committee will now study the Pennsylvanian and Mississippian which also were series in the old Carboniferous. The chairman has been directed to appoint another sub-committee of seven members of the committee on geologic names and correlations to study the question of nomenclature and classification of the entire Carboniferous in North America. This sub-committee can be organized as soon as the incoming president has appointed the chairman and filled the vacancies in the main committee.

Other problems that are being discussed and will be followed this year are the correlation of Mississippian formations in Illinois, Indiana, and western Kentucky; the Cretaceous section both of the Rocky Mountains and the Gulf Coast, and particularly the relation of electric-log correlations and existing formations in Louisiana, Arkansas, Texas, and Mississippi; and the correlation of the Permian of Texas, Oklahoma, Kansas, Nebraska, and the Rocky Mountain states that is being undertaken by the associate editors of the Permian volume now in preparation.

The committee proposes to continue active work on general and regional problems of nomenclature that will assist petroleum geologists and advance our science.

John G. Bartram, *chairman*

Exhibit VI. Report of Chairman of Research Committee

The three most important problems of the research committee, it seems to me are: (1) personnel, (2) what to do, and (3) how to do it.

The answer to the first problem, personnel, is that we have attempted to get together a group of men who first of all will work. Furthermore, there is a geological distribution within our committee members ranging from those concerned with the Tertiary to those concerned with the Ordovician sediments; there is a geographical distribution from California to New York; and there is a distribution of interest from everyday commercial petroleum geology through geophysics, geochemistry, petroleum engineering, teaching, and into pure philosophical geology.

The answer to the second and third problems, what to do and how to do it are more or less interdependent. With a committee as diverse in its interests as this, it becomes a real problem to know what to do and then how it is to be done. Each member is busy with his own affairs, he is generally geographically separate and has little or no direct contact with others on the committee. It requires not less than two months to get replies from the committee on simple questions and over six months, by experience, to get replies on questions involving thought and study. The result is that we have not waited to get the opinion of the committee as a whole in starting on new projects, but have gone ahead when there seemed to be a demand for some project or action and notified the majority of the committee afterward. The procedure generally has been that the chairman learns of a possible project from

some source and after discussing it with such persons as he comes in contact with—possibly many of whom are not actually on the committee, and becoming convinced of its need, the project is started. A recommendation is made to the president for the appointment to the research committee of someone whom we believe to be the best fitted to handle the project, and the result is that most of the committee is now composed of members who have specific jobs to perform.

It may be that you will think some of these projects are not the sort of thing that we should be doing as a research committee and if you do we will be very happy to learn of your ideas and suggestions. We have no fixed plan or approach and have more or less adopted the project which at the time seemed worth while and could be developed with our limited means of time and money. Following are the various projects upon which we are working at the present time together with recommendations by the research committee for action by the Association.

1. Sponsorship of a special volume on the subject of the "Permian System of the United States West of the Mississippi River" to be published by the aid of the revolving publication fund of the Association and to be written by various members of the Association under the editorship of Ronald K. DeFord, E. Russell Lloyd, and T. C. Hiestand. Work on this publication is well under way although it may be four or five years before the volume is finally published.

2. Sponsorship of a special volume to be published through the aid of the revolving publication fund on the subject "Stratigraphic Oil Fields in the United States." This volume will contain complete descriptions of the geology, and production of fifty or more oil fields each of which is characterized by having one side of the producing area limited by the edge of porosity in the reservoir rock. Thus sand-lens pools, shoestring pools, overlap pools, and similar types will be described. Regional editors are D. Perry Olcott, south Mid-Continent; N. W. Bass, north Mid-Continent; Theron Wasson, eastern states; Ross L. Heaton, Rocky Mountain states, and W. S. W. Kew, California. It is hoped publication will be in 1941. To date there are approximately fifty-two fields, the descriptions of which have been promised by various members of the Association.

3. A contribution of $300 was made available for the use of Roger R. D. Revelle and Francis P. Shepard for the purpose of constructing a bottom-sediment trap for measuring the movement of bottom sediments in the vicinity of the Scripps Institution of Oceanography at LaJolla, California. Following is an excerpt from a recent letter from Dr. Revelle.

> Shepard and his assistant, Kenneth Emery, have been here for about three weeks; during which time we have had a model of the type of trap we hope to use constructed by a local tinsmith and it is now being looked over for "bugs." One of the current meters to be used in already constructed, while the other type is still only in the rough design stage. Before actually setting any instruments out on the shelf, we hope to test various methods of catching moving sediments in the laboratories of the Soil Conservation Service at California Tech and at the end of our pier. I shall try to keep you informed of our developments.

4. The research committee assisted in coördinating the geologists of Houston and the Gulf Coast area with the United States Coast and Geodetic Survey to the end that a number of bottom sediments were made available to the petroleum geologists taken from accurately located points in the Gulf

of Mexico. These samples are being examined and results will soon be available through the efforts of a committee of which F. W. Rolshausen is the chairman.

Following is a progress report on the results of this work by F. W. Rolshausen, chairman of the Gulf Coast geologists who are interested in this project.

During 1939 through the courtesy of the Coast and Geodetic Survey, and Captain G. C. Mattison, Commanding Officer of the ship "Hydrographer," approximately 130 bottom samples were collected from the Gulf of Mexico.

Most of these samples were collected from an area extending 25 miles south of the mouth of the Rio Grande and 60 miles north and approximately 60 miles east out into the Gulf. Most of the samples were collected from depths varying from 40 feet to 250 feet and a few from 250 to 600 feet and one from 9,990 feet.

After plotting the location of the samples, profiles were selected and the samples are now being examined. Slides of the forams, ostracods, gastropods, and pelecypods are being made.

Upon completion of the examination, Mr. Garrett will study the ostracods, Dr. Hanna the gastropods and pelecypods, Mr. Israelsky the foraminifera, and Mr. Lowman the grain size and heavy minerals.

Some of the samples have not been worked so no results or conclusions can be reported to date. We hope to complete this work and have it ready for publication some time in 1941.

J. B. Garrett
M. A. Hanna
M. C. Israelsky
S. W. Lowman
F. W. Rolshausen

5. F. M. Van Tuyl and Ben H. Parker, both of the Colorado School of Mines, have been working for several years on a coördination of our knowledge on the problem of the migration and accumulatiion of oil and gas. Their preliminary report has been submitted. It comprises approximately 400 pages of typewritten material and is the result of a vast amount of detail work.

Fourth Annual Report on Study of Time of Origin and Accumulation of Petroleum

The relevant data bearing on this subject assembled from the literature together with data submitted in answer to letters and questionnaires and to the appeal for coöperation, published in the February, 1937, *Bulletin* of the A.A.P.G., after being classified and coördinated, have been incorporated in a 372-page report. The sum of one hundred dollars ($100.00) granted by the research committee for stenographic service was expended in this undertaking.

Three copies of the compilation were submitted to chairman Levorsen on September 6, 1939, for review by the research committee. He has endeavored to circulate the report in such a way that each member of the committee would have a chance to criticize and express his opinion regarding its disposition prior to this meeting.

It is hoped that the material may ultimately find its way into print, and that further observations and study on this subject may thus be stimulated. The writers desire to act as a clearing house under the continued sponsorship of the research committee for the collection of additional evidence not sufficiently complete to justify special publication.

If it is the wish of the committee to retain the sponsorship, the study may be continued either as a separate project or consolidated with the work of the conference group on "Migration and Accumulation of Oil" with which we are both connected.

F. M. Van Tuyl and Ben H. Parker

Golden, Colorado
April 8, 1940

The research committee recommends the publication of the report on "The Time of Origin and Accumulation" by Van Tuyl and Parker in some inexpensive manner, such as mimeograph or planograph, this report then

to be distributed to those who request it either free or not to exceed the estimated cost.

6. A committee of geologists appointed by the National Research Council has been working for about five years on a structure map or "tectonic" map of the United States. The preliminary work has been done and the Association, upon the recommendation of the research committee, contributed $300 to defray the drafting onto one base map of the different sections of the map as prepared by various workers. This preliminary map is now ready for correction preparatory to the preparation of the finally engraved sheets in colors. A copy will be sent to each geological society and the president of the society asked to appoint someone to see that the map is passed around among those companies and individuals who might have information with which to make corrections on the map.

7. Several years ago the Tulsa Geological Society sponsored a coöperative project covering the relation of oil analyses to stratigraphy. The project was under the chairmanship of L. Murray Neumann, and the committee consisted of three geologists and three chemists. This is now one of the projects of the research committee, and upon recommendation of the research committee the executive committee made available for the use of this project the sum of $750. This money is being used to defray the cost of oil analyses which are being made by the Bureau of Mines experiment station at Bartlesville, Oklahoma. A great deal of work has been done on this project, and considerable progress is being made. Following is a report on this project by N. W. Bass.

Tulsa Geological Society Research Committee Project: Geologic Relationships of Crude Oils

MEMORANDUM to Mr. A. I. Levorsen, Chairman
Research Committee, American Association of Petroleum Geologists

About 350 to 375 samples of crude oil mainly from Oklahoma, including Oklahoma City, Seminole, and Osage County, and some from southeastern Kansas have been investigated. Our comparisons of the crudes have been made by using the correlation-index method devised by Harold M. Smith. The comparisons suggest that each oil pool may contain a distinctive crude but that some crudes have many features in common which make it possible to divide them into classes.

The composition of the crude from each pool in Ordovician beds along the Nemaha Granite Ridge, from Noble to El Dorado, appears to differ from that from every other pool. The Ordovician rocks in these fields, however, have essentially similar structural histories.

At Oklahoma City crudes from six Pennsylvanian sands differ from the crudes from the Simpson and Arbuckle and differ among themselves. It is particularly interesting that at Oklahoma City, crude from the Prue sand in the Cherokee only 50 feet or so above, and locally in contact with, the deeply eroded Ordovician rocks, is unlike the crude in the Ordovician but is similar to the crude from the Burbank sand of the Burbank field 90 miles away.

In contrast to the relationships along the Granite Ridge, crudes from the "Wilcox" sands in 7 pools east of the Ridge whose structure and stratigraphy are widely different, are similar to each other and not greatly unlike the Simpson crude of Oklahoma City.

The "Wilcox" crudes from several pools near Bristow, are distinctly unlike though the structure and stratigraphy in the fields are essentially similar.

In Osage County the greatest contrasts in the crudes were found in those from Bartlesville sand lenses that lie about 50 feet apart stratigraphically. Some samples from Bartlesville sand pools in Osage County, Oklahoma, and from Burbank sand pools in Cowley, Butler, and Greenwood counties, Kansas, suggest that pools containing crudes of like nature lie in narrow belts that are probably equivalent to the belts of offshore bars that formed at the time of the deposition of the sand.

During the next year we hope to concentrate our investigation on from two to three relatively small areas including (1) Cherokee sands in morthern Oklahoma, and (2) Simpson sands in the Granite Ridge. It is planned to collect and analyze about 200 new samples of crudes. It is hoped that this additional investigation will reveal whether the relationships that are now suggested are valid. We shall need $1,500 to pay salaries of the analysts.

The total of our expenditures from the A.A.P.G. research allotment of $750 was $619.03 on April 1, 1940. I believe the analyst is still employed and his salary for April will add $50, making the total on May 1, 1940, $669.03.

(Signed) N. W. Bass
April 5, 1940

The research committee recommends that a grant be made of whatever portion of the sum of $1,500 that should be necessary to complete the present program of the Tulsa Geological Society on correlating oil analyses with stratigraphy.

8. Upon the recommendation of the research committee the executive committee made available a fund of $1,000 for the purpose of aiding in the completion of research projects which are of particular interest to petroleum geology. Notice of this fund was published in the *Bulletin* (Vol. 23, p. 757) and letters containing the announcement were sent to all colleges having geological departments in the United States. To date there has been but one application for a grant from this fund. This is disappointing to the chairman, since it probably indicates a very small amount of research in the field of petroleum geology.

The grant mentioned was for the amount of $300, and was made available for the use of Roger Revelle and Francis Shepard for the purpose of constructing a bottom-sediment trap to be used in the vicinity of the Scripps Institution of Oceanography at LaJolla, California.

The research committee recommends that this grant of $1,000 for the year 1939–1940 which was made for the use of the research committee in promoting research in petroleum geology and of which only $300 was appropriated be renewed for the year 1940–1941.

9. The research committee recommends the appointment by the executive committee of a committee to study and report on the advisability and need for another medium of publication, that is, mimeographed sheets or booklets to be published from time to time as the material becomes available. These publications to be prepared as cheaply as possible and to be sold to members at approximately their cost. The material to be so published would be of local or limited interest and less formal than required by the standards of the *Bulletin*. The following type of material is suggested as suitable for such publication.

1. Detailed stratigraphic studies, particularly of the grade of Ph.D. theses. The colleges are full of this material—much of which would be of great interest to a limited number of people
2. Progress reports of the research committee conferences and any other type of progress report
3. Study-group material. Results of study groups, such as that published by the San Antonio society
4. Road logs *et cetera*
5. Extended reviews or even reprints of important papers in the foreign technical press

10. Several surveys were made as follows.

(a) A survey of the college students who majored in geology was made

as of January, 1938 and 1939. (The results were published in the *Bulletin*, Vol. 23, pp. 1280–81.) An average increase in number of approximately 40 per cent in 1939 over 1938 was noted. Similar data compiled for January, 1940, show an increase of only 3 per cent over 1939. There are over 2,500 students majoring in geology in the colleges of the United States.

(b) A survey was made of the colleges attended by members and associates of the Association. (The result was published in the *Bulletin*, Vol. 23, pp. 1117–23.)

Five Highest Ranking Colleges in Number of Undergraduates

1. University of Oklahoma	397
2. University of Texas	186
3. Stanford University	177
4. University of California	156
5. University of Nebraska	110

Five Highest Ranking Colleges in Number of Graduates

1. University of Chicago	147
2. University of California	92
3. Columbia University	78
4. University of Oklahoma	76
5. Stanford University	68

Five Highest Ranking Colleges in Total Number of Undergraduates and Graduates

1. University of Oklahoma	473
2. University of California	248
3. Stanford University	245
4. University of Chicago	245
5. University of Texas	235

Five Highest Ranking States in Total Number of Undergraduates and Graduates Including All Colleges Reporting within the State

1. California	619
2. Oklahoma	528
3. Texas	406
4. Illinois	355
5. New York	248

This survey is of interest in that it shows the colleges and areas which are chiefly responsible for the training and education of our members.

11. A new venture has been started which consists of the organization of five conference groups to be held from 2:00 to 5:00 P.M. on the afternoon preceding the annual convention, April 9. (Described in the *Bulletin*, Vol.24, pp. 401–02.) The purpose is to study more intensively and collectively some of the fundamental problems of petroleum geology. Each group consists of a leader, and possibly one or more assistants, each of whom are members of the research committee, and as many other members of the Association as show sufficient interest to attend and take part in the discussions. The results, method of attack, and scope of the conferences will depend on the leaders and those who participate. The conferences which have been organized are:

1. Sedimentation and Reservoir Rock: leader, E. Wayne Galliher
2. Oil-Field Waters: leader, L. C. Case
3. Origin and Evolution of Oil: leader, Monroe G. Cheney
4. Migration and Accumulation of Oil: leader, F. M. Van Tuyl
5. Relation of Oil Analyses to Stratigraphy: leader, N. W. Bass

Other conferences will be arranged whenever a group wishes to get together and discuss some fundamental problem. We believe that if we can get together

100 to 500 years or more of experience in petroleum geology around a table and focus it on some one subject that we can expect some results.

12. The subject for the annual evening round-table discussion of the research committee at the Chicago meeting, to be held on the evening of Tuesday, April 9, is "Geochemical Exploration (Soil Analysis)." Formal presentation of the subject will be by E. E. Rosaire and Eugene McDermott, after which there will be one to two hours of open-forum discussion.

13. The research committee is sponsoring the program for one afternoon, Wednesday, 2:00 to 4:30 P.M., April 10, at the Chicago convention. This program is to be a symposium on "New Ideas in Petroleum Exploration," with particular emphasis on new techniques, philosophies and practices with their significance to petroleum geology. Following the formal presentation by six speakers the meeting will be opened for an hour of discussion and open forum. The speakers and discussion will be keyed to the present and future.

A. I. LEVORSEN, *chairman*

EXHIBIT VII. EIGHTH ANNUAL REPORT OF COMMITTEE ON APPLICATIONS OF GEOLOGY

In welcoming geologists to the fifty-first annual meeting of the Geological Society of America at New York City in December, 1939, Nicholas Murray Butler, president of Columbia University, stated:

> One of the extraordinary things, however, about science—perhaps the most extraordinary thing—is that despite its really wonderful progress during the last 100 years it has not yet been able to impress its method and its ideals upon public opinion.

Granting that "the public mind is as remote from being guided by scientific method as if that method were not in existence," there exists the need and problem of exerting further efforts to bring science and its efficiency to the people. Geology in particular is appreciated by the laity, and it is the purpose of our committee to instigate means of educating them in its continuous usefulness and practical application—and to encourage other geologists to do so. Furthermore, it is the intention of our committee to see that the Association is brought more to the attention of the Nation's leaders—particularly its high professional standing, its scientific and practical results and usefulness, and its ability to contribute leaders in local, national, and scientific affairs from its own ranks.

Apropos of certain aims of our committee hereinbefore set forth, especial commendation is deserved by Chalmer J. Roy of the Louisiana State University, for his efforts in organizing and directing a speakers' service toward bringing the Association to the attention of widespread selected groups and imparting to them the results of our scientific and practical researches and general usefulness. He received good responses from district representatives regarding speakers, and will arrange an annual list of semi-official Association speakers for tours—a system followed by several prominent scientific societies.

In addition to addressing himself several societies in Louisiana on geochemistry and on geological methods used in finding oil in that state, Professor Roy arranged for other members of the geological department of the State University to address local groups and societies on subjects of general geologic interest.

As chief of the Naturalist Division, Branch of Research and Information, National Park Service, Earl A. Trager brings geology and other natural sciences to thousands continuously and effectively throughout the United States and possessions. Additional exhibits, illustrating the geology in many national parks, were set up in the parks and about a dozen publications of geologic interest were prepared, such as the one on the Great Sand Dunes of Colorado, by C. H. Wegemann. Exhibits were maintained at the International Petroleum Exposition in Tulsa, Oklahoma, and at other places. Research projects carried out under his direction in his organization and in coöperation with other Government scientific bodies were many, varied, and widespread—for instance, the geologic history of Crater Lake, Oregon; and geology of Crystal Cave, Sequoia National Park, California. In addition, his organization issued reports on mineral appraisals, water resources, and dam sites.

H. S. McQueen, assistant State geologist of Missouri, interviewed officials of the following institutions in Missouri to ascertain to what extent they are bringing geology to the public: Drury College, St. Louis University, University of Kansas City, University of Missouri, Washington University, Missouri Geological Survey, and the Missouri School of Mines. It was found that geological talks of a popular nature were broadcast by all but two of them during the year and that such talks are part of a definite program at the University of Kansas City and at Washington University. Public lectures on geology were given by members of the geological departments of all the aforecited institutions to grade and high schools and to science and civic clubs throughout the state, it being clearly evident that the public interest in geology therein is increasing. Furthermore, these institutions furnished the local press with geologic items of interest informally and in many instances were authors of, or advisors in, the preparation of press releases. Inquiries on various geological problems were answered, illustrated lectures were given before groups visiting the institutions, free field trips were conducted, local geological clubs were sponsored, and assistance was given to various other scientific and engineering societies.

The Missouri Geological Survey continued its excellent work of educating the public in geology—particularly in problems confronting local water-well drillers. It prepared and distributed rock and mineral samples to high and grade schools in the state and, in coöperation with the State Board of Health, supervised the drilling and casing of all wells drilled for public water supplies. The Survey continued its analysis of wildcat drilling activities in northern Missouri before various groups and in written articles.

Although Carey Croneis, of the University of Chicago, was busy last year with additional administrative duties in connection with the forthcoming semi-centennial anniversary of the University, he gave the usual number of popular lectures during the year, the most important ones being before the combined engineering clubs of Fort Wayne, Indiana, with an audience of 1,200, and a similar address before 600 members of the Michigan Teachers Association at Western State Normal College, Kalamazoo. In addition, he gave eighteen lectures on various phases of geology to students in the junior colleges of the metropolitan Chicago area. Furthermore, during the year he was a representative of geology and geography on a national committee of the American Association for the Advancement of Science, designated

as the "Committee for the Improvement of the Teaching of Science."

Hal P. Bybee, geologist in charge of university lands, and professor of geology, University of Texas, continued his geological work with the Boy Scouts of southern Texas, had charge of the regional meetings of the Texas Academy of Science, and otherwise carried out his well established work in bringing geology to the public. The South Texas Geological Society now awards two years annual dues in our Association to the outstanding student in the department of geology at the University of Texas.

B. B. Weatherby, president of the Geophysical Research Corporation, prepared an exhibit last fall for the Museum of Science and Industry in Chicago, in which a sample of "Wilcox" sand, roughly in the form of an 8-inch cube, was set alongside a small beaker of oil, the oil in the latter being approximately the amount which could normally be recovered from such a volume of sand. The purpose of the exhibit was to dispel the popular conception of rivers and pools of oil. As a result of the many favorable comments on this exhibit, a more elaborate one will be set up at the forthcoming International Petroleum Exposition, showing two dozen cores of different producing oil sands and limestones from all parts of the world and test tubes containing the approximate amount of recoverable oil from each core.

Dr. Weatherby has prepared a long article for publication in the daily newspapers of Tulsa at the time of the International Petroleum Exposition, covering advances in exploration during the past two years. As chairman of the Board of Trustees of the Tulsa Public Library, he is building up a fine reference section, particularly in geology, and as chairman of the sub-committee on geology, International Petroleum Exposition, will arrange for other exhibits of popular and scientific interest.

Harold W. Hoots, chief geologist of the Richfield Oil Corporation, organized evening meetings in southern California for the purpose of bringing popular talks on geology to the layman. His efforts to assemble available private geological libraries in places easily accessible to geologists and laymen were well rewarded. In addition, he spent much time advising and encouraging unemployed young geologists and students at various universities on the Pacific coast.

Luther E. Kennedy, of the Peters Petroleum Corporation, Tulsa, Oklahoma, was instrumental in the publishing of several popular articles on geology in the press of his district and describes the special efforts made by the Tulsa Geological Society to attract the public to its meetings when noteworthy persons speak. The excellent technical division of the Tulsa Public Library has had an increased demand from the public for books and articles on geology as a result of notices in the local press of various available geological publications. Outlines of geology are given by science teachers in the high schools of Tulsa, and many teachers take student groups on field trips to quarries, coal pits, *et cetera*, in that general area. N. W. Bass, of the United States Geological Survey, has addressed a number of civic groups in Oklahoma, and geologic and geophysical exhibits will be set up at the forthcoming International Petroleum Exposition at Tulsa in May.

In addition to many varied official contacts with the public as geologist in the United States Geological Survey at Denver, Colorado, the chairman of the committee delivered geological addresses during the past winter, as here shown.

1939	*Organization*	*Place*
Nov. 7	Colorado Engineering Council	Denver
Dec. 15	American Society Mechanical Engineers	Denver
1940		
Jan. 11	American Association Purchasing Agents	Denver
Jan. 20	Colorado Society Engineers, annual meeting	Denver
Jan. 23	University of Colorado	Boulder
Feb. 16	American Society for Metals	Denver
Mar. 5	Reserve Officers Corps, U. S. Army	Denver
Mar. 15	Colorado School of Mines, annual Engineers' Day	Golden
Mar. 20	Colorado Mountain Club	Denver
Apr. 12	The Executives' Club	Chicago

On March 2, the chairman participated in a job conference at the University of Colorado, acting as advisor to students in geology regarding the employment outlook in that science for seniors. On March 7 and 13, aided by A. E. Brainerd, he was counsellor on the Fourth Annual Program sponsored by the Colorado Engineering Council in coöperation with the Denver branch of the National Vocational Association. In addition, he continued his duties as secretary of the Colorado Scientific Society, as a member of the Colorado Engineering Council—the supervisory body of all engineering societies in the state—and as counsellor in geology to the Denver Public Library, whose technical division is one of the largest and most complete in this country.

Other members of our Association in the Rocky Mountain region coöperated in bringing the science of geology to the laity by means of the public meetings of the Rocky Mountain Association of Petroleum Geologists and addresses at civic meetings of various kinds. Of particular interest and importance was the completion of Berthoud Hall, at the Colorado Schoool of Mines—a new geological and geophysical building whose fine museum in charge of Professor J. Harlan Johnson, curator, is invaluable to the geologists in this vicinity and will further stimulate the layman to appreciate and understand geology.

The present committee was organized after the annual meeting of the Association at Oklahoma City in March, 1939. It is, therefore, still incomplete in personnel and in the organization of methods of attaining some anticipated objectives.

C. E. Dobbin, *chairman*

Exhibit VIII. Report of Committee for Publication

The committee for publication, composed of twenty-four members, was organized by the Association to assist in securing desirable manuscripts for publication in the *Bulletin*.

As in previous years, committee members were selected from each of the important oil-producing areas in the United States so that each district has had at least one member in close touch with local developments. Many prospective authors have been interviewed and urged to prepare manuscripts for publication. Already some of these papers have materialized and, no doubt, many more will be presented during the coming year. The results of the work of the committee can not be felt or evaluated immediately, since it usually takes considerable time for the solicited papers to be ground out.

This year, authors have been urged to prepare especially two types of papers, first: short papers for "Geologic Notes" giving the location, geologic structure, and technical reason for drilling of recently discovered pools, and, second: more comprehensive papers bringing up to date our geologic information on fields or areas where papers were written ten or fifteen years ago and where much additional information is now available. These two types of papers have been urged in addition to, and not to the exclusion of, any other good material.

Several committee members have offered suggestions for the consideration of next year's committee. Two of the most important of these are here listed.

L. W. MacNaughton

It is believed that a definite program should be followed in publishing information on oil and gas fields in the *Bulletin*. With this thought in mind, these three suggestions are made:

(1) Each discovery well should be described under "Geological Notes."
(2) A descriptive article on each of the more important fields should be written as soon as development has revealed the necessary geological data.
(3) A complete article should be prepared on each of the very important fields when it nears the end of its productive life.

The first suggestion is made because it seems important that at least one professional periodical, preferably ours, should contain a note about every discovery oil and gas well. It is obvious that this record should adhere strictly to factual data such as location, depth, date and method of completion, geological section penetrated, list of oil and gas showings and a description of the producing zone. Comments on the geological, geophysical, or other reasons used in locating the well may also be included. Since these notes should appear within a month after the completion of the discovery well, it might be wise to publish them anonymously or simply over the name of the committee. This course would avoid delay and would not identify any particular author with the field during this initial stage of development.

As these new fields develop, it soon becomes apparent which are of sufficient geological or economic importance to deserve a more extensive article. This type of field paper should describe fully the history, development, and all phases of the geology of the field and should generally include some notes on relevant data such as production practice and costs. Since these articles are generally written near the end of the period of development and before much of the production history is known, certain conclusions must necessarily be conjectural and thus be subject to change.

Because of this, the final suggestion is to have a complete article on each of the most important oil and gas fields as they near the end of their productive lives. This would afford one the opportunity of reviewing and correcting, if necessary, the previous information published and also presenting good data on the methods of production and the recoveries of oil and gas. Such an article would be most valuable as it would serve as a criterion in the study of the newer fields, especially in the estimation of oil and gas reserves.

These suggestions have been made because it is believed that more consistent recording of information on oil and gas fields in the *Bulletin* would increase its usefulness.

Carl C. Addison

We are all proud of the high standard which has been set in the *Bulletin* in recent years, and I am sure that none of us would desire to relax this standard to facilitate securing manuscripts. On the other hand I feel that perhaps too much emphasis is being given to the matter of encouraging authors to arrive at conclusions. Personally I feel that a very important "by-product" of the oil industry is a wealth of scientific fact. As oil men we live in a very hurried world and none of us pretends to have time to make the most of the facts we obtain. Many of us feel that we are capable of analyzing our data and reaching an acceptable conclusion but this is a process which requires much time and access to a good library. So, in many cases, we are failing to record our facts because we do not have time or facilities to reach careful conclusions. This, I believe, is a mistake.

In my opinion it is desirable to leave behind us a complete record of our facts. No oil field, however unimportant, fails to reveal information which is important in interpreting the broader aspects of the geology of the area. Should we not then encourage factual records of our various pools in which stratigraphic, structural, and reservoir conditions are described accurately and well, even though it may be impractical at the time to attempt regional correlation, determination of age of folding, origin of porosity, source of oil, etc.? Certainly if these facts are well recorded and in considerable detail, some later investigator with more time and better facilities will be able to correlate the work of various contributors and arrive at better over-all conclusions than we are capable of at present.

Thus I propose that shorter contributions giving facts be encouraged to a greater degree than in the past few years along with the more ambitious efforts, which are now given preference.

The chairman of this committee feels that the two foregoing suggestions are worthy of serious consideration and if put into practice will materially enhance the value of the *Bulletin*. MacNaughton's idea of having members of the committee prepare the "Geological Notes" on field discoveries should speed up the presentation of these important data. This task should be made a definite part of the committee's function.

It seems evident that a note of warning should be sounded in respect to promiscuous or over-zealous efforts on the part of committee members. The acceptance of a paper for publication in the *Bulletin* should be a distinct honor for the author and such a feeling should not be killed by too much soliciting.

If, at the present time, it is difficult to obtain a goodly number of first-class papers, we should look for the obvious reasons why such is the case, rather than to keep prodding our membership and begging for that which should be naturally forthcoming. There is one outstanding reason which this committee has bumped into on all sides. This is the reluctance or absolute refusal of company officials or their legal departments to release information concerning fields or leases in which they are interested. Sometimes there is a political reason involved, but more often it is one of economics tending to indicate that the company might be injured by publishing certain facts and going on record as to relative lease values, etc., etc. At other times it is the desire of certain individuals or companies to keep to themselves any secret or valuable data which they might have collected, and by the time they are willing to have them published, they no longer have news value. Whether this difficulty can be overcome is problematical. It seems to be increasing year by year as new state and federal regulations appear, and as competition becomes keener. Perhaps the Association and this committee should direct part of their attention to company officials in an attempt to show them the value of the interchange of ideas and data as published in the *Bulletin*.

ROBERT E. RETTGER, *chairman*

EXHIBIT IX. REPORT OF REPRESENTATIVE TO NATIONAL RESEARCH COUNCIL

Herewith I submit for your approval my report as representative of the Association on the Division of Geology and Geography of the National Research Council. The Division held its annual meeting on April 29, 1939, in Washington, D. C. Summaries of the work accomplished during the year by the several committees of the Division were presented and discussed. I shall briefly review those which seem to be of particular interest to our members.

Parker D. Trask, chairman of the Committee on Sedimentation, reported completion of 6 bibliographies on different fields of sedimentation, as follows:

1. Sedimentation Studies by the Soil Conservation Service, 1938–39, by Carl B. Brown
2. Recent German Studies of Sediments, by Carl W. Correns
3. References on Glacial Sediments, 1934–38, by R. F. Flint
4. Recent Russian Publications on Sedimentation, by P. D. Krynine
5. References on the Transport of Detritus, by L. G. Straub
6. Bibliography of Recent Advances in the Field of Calcareous Sediments, by R. O. Vernon

These may be obtained in mimeographed form in the "Report of the Committee on Sedimentation: 1938–1939," sold by the National Research Council. They were reviewed on page 386, in the Association *Bulletin* of February, 1940. Recommendation was made that this committee continue preparing such summaries of progress in the study of sedimentation, but that more emphasis be shifted from recent to ancient sediments. Toward this end the personnel of this committee was reorganized.

Joseph A. Cushman reported as chairman of the Committee on Micropaleontology. Among other things, he again referred to the importance of studying environmental conditions under which faunas are developed, and he emphasized the fact that faunas previously regarded as of different age may actually belong to contemporaneous environments of different character.

Under the chairmanship of W. H. Twenhofel, a comprehensive analysis was made to determine what should be the scope of the functions of the Committee on Conservation of Scientific Results of Drilling. Previously there had been a good deal of doubt as to just how far this committee might and should go in its activities. After much deliberation, and after a study of the answers to a comprehensive questionnaire sent to all State geological surveys, the conclusions were reached:

(1) That such work as it may do should be largely of an educational character rather than that it be concerned with acquiring samples and allocating them to designated depositories;

(2) That the latter work should be left to the various state organizations of a geological character as they are much better informed as to what is being done in their respective states than the Committees could possibly be;

(3) That possibly the Committee's influence and prestige may aid these various organizations to procure from the water-well drillers the samples and cores taken from the wells drilled by them, doing this by educating the drillers on the desirability of coöperation between them and their respective state organizations, and by showing to them how study of samples and cores is likely to produce valuable information which may have financial returns; and

(4) That it is probably not "worth while for the Committee to concern itself with the petroleum organizations or the drillers of petroleum wells as these organizations are manned by competent geologists who work in close cooperation with the state organizations functioning as geological surveys. These geologists direct the drilling and they are fully acquainted with the importance of knowledge of the subsurface geology and the extent to which this knowledge may be advanced by drilling.

Carl O. Dunbar, chairman of the Committee on Stratigraphy, reported that 6 of the projected set of 13 correlation charts had been completed. These covered the following systems: Cambrian, Ordovician, Silurian, Cretaceous (of the Atlantic and Gulf Coastal plains), and Tertiary. These charts, he stated, would eventually be published by the Geological Society of America.

C. R. Longwell, chairman of the Committee on Tectonics, reported excellent progress on the tectonic map of the United States. As you know, our

Association, and especially our Research Committee, has been actively interested in this project. At present writing, the map is already for sale in completed form.

The Committee on Research in Earth Sciences now has several subcommittees in its Geologic Section. A. I. Levorsen is chairman of one of these, the Subcommittee on Petroleum Geology, which was organized "to keep the parent committee informed as to where research in petroleum geology impinged upon other research in geology," as explained by Isaiah Bowen, chairman of the parent committee in his annual report. I might make a suggestion here for those of our members who may next serve as chairman of the Subcommittee on Petroleum Geology and as Representative of this Association on the Division of Geology and Geography. There is a very good chance for duplication in the annual reports of these two members since the functions of both seem to some extent to overlap. No doubt such duplication can easily be avoided by coöperation.

For those who may be interested, I am listing here the names of our Association members who are also members of the several committees referred to in the previous paragraphs.

Committee on Sedimentation (16 members)

Parker D. Trask, chairman	A. C. Trowbridge
W. C. Krumbein	W. H. Twenhofel
H. B. Milner	T. Wayland Vaughan
R. Dana Russell	

Committee on Micropaleontology (10 members)

Joseph A. Cushman, chairman	Henry V. Howe
Carey Croneis	Raymond C. Moore
Alva C. Ellisor	M. T. Natland
G. Dallas Hanna	Helen J. Plummer

Committee on Conservation of the Scientific Results of Drilling (9 members)

W. H. Twenhofel, chairman	E. H. Sellards
Marcus A. Hanna	W. L. Thom, Jr.
F. H. Lahee	L. E. Workman
H. S. McQueen	

Committee on Stratigraphy (11 members)

Carey Croneis	L. W. Stephenson
B. F. Howell	W. H. Twenhofel
Raymond C. Moore	C. E. Weaver
John B. Reeside, Jr.	

Committee on Tectonics (17 members)

Philip B. King, vice-chairman	W. H. Monroe
Charles H. Behre, Jr.	W. T. Thom, Jr.
A. I. Levorsen	A. C. Waters
T. S. Lovering	

Committee on Research in Earth Sciences (13 members)

A. I. Levorsen	T. S. Lovering	T. Wayland Vaughan

FREDERIC H. LAHEE

EXHIBIT X. REPORT OF RESOLUTIONS COMMITTEE

BE IT RESOLVED, That we, the members of the American Association of Petroleum Geologists, express our appreciation and sincere thanks to the following.

The Illinois Geological Survey.
The Illinois Geological Society.
The Indiana Geological Survey.
The University of Chicago.
The University of Illinois.
The Northwestern University.

All those who have worked and contributed to the success of our twenty-fifth annual meeting and particularly to the following.

Verner Jones, general chairman of the convention committee and all other chairmen and members of each committee.

Mrs. Carl B. Anderson, chairman, and other members of the ladies' committee.

M. M. Leighton, chief of the Illinois Geological Survey, Urbana, Illinois, for his "Address of Welcome" and for arranging field trips.

Alfred H. Bell, chairman of the technical program.

J. V. Howell, chairman of arrangements.

Carey Croneis, chairman of technical equipment.

Don L. Carroll, chairman of publicity and exhibits.

E. F. Stratton, chairman of dinner-dance arrangements.

L. M. Clark, chairman of registration and reception.

E. W. Ellsworth, chairman of the finance committee.

Robert Maynard Hutchins for his address to members of the American Association of Petroleum Geologists.

The Stevens Hotel, and especially L. B. Raugh, for coöperation and for generously placing at our disposal rooms and other facilities for holding our meetings.

The various clubs and officials of Chicago for their coöperation.

The various oil, industrial, drilling, and supply companies for their contributions, and exhibitors for their displays.

Be it further resolved, That the sincere thanks of the Association be given to the executive committee for the efficient manner in which they have conducted the affairs of the Association during the past year.

Be it further resolved, That the sincere thanks of the Association be given to the Society of Economic Paleontologists and Mineralogists and the Society of Exploration Geophysicists for their splendid coöperation.

Be it further resolved, That the sincere thanks of the Association be given to:

Henry A. Ley
L. Murray Neumann
Ed. W. Owen
Walter A. Ver Wiebe and
J. P. D. Hull

for their untiring efforts during the past year.

Be it further resolved, That these resolutions be included in the minutes of the meeting and copies be sent to the individuals and organizations named.

Carleton D. Speed, Jr., *chairman*
Phil F. Martyn
H. H. Arnold

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

L. C. Snider, *chairman*, Petroleum Advisers, Inc., New York City
Ed. W. Owen, *secretary*, L. H. Wentz (Oil Division), San Antonio, Texas
Henry A. Ley, Southern Cross Oil Company, San Antonio, Texas
John M. Vetter, Pan-American Prod. Company, Houston, Texas
W. A. Ver Wiebe, University of Wichita, Wichita, Kansas

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL

Frederic H. Lahee (1940)

FINANCE COMMITTEE

E. DeGolyer (1940) Wallace E. Pratt (1941) W. B. Heroy (1942)

TRUSTEES OF REVOLVING PUBLICATION FUND

Alexander Deussen (1940) George S. Buchanan (1941) E. Floyd Miller (1942)

TRUSTEES OF RESEARCH FUND

Sam M. Aronson (1940) Arthur A. Baker (1941) Walter R. Berger (1942)

BUSINESS COMMITTEE

H. K. Armstrong (1941)
W. N. Ballard (1941)
N. Wood Bass (1941)
R. L. Beckelhymer (1942)
A. H. Bell (1941)
J. Boyd Best (1941)
L. D. Cartwright (1941)
W. W. Clawson (1942)
Carey Croneis (1942)
J. I. Daniels (1941)
R. K. DeFord (1941)
C. E. Dobbin (1941)
H. L. Driver (1941)
E. C. Edwards (1942)
James R. Gibbs (1942)
Delmar R. Guinn (1941)
Henry A. Ley (1941)
J. H. McGuirt (1941)
C. C. Miller (1941)
C. L. Moody (1941)
H. H. Nowlan (1941)
Ed. W. Owen (1941)
Paul H. Price (1941)
Roger H. Sherman (1941)
S. E. Slipper (1941)
L. C. Snider (1942)
H. B. Stenzel (1941)
L. W. Stephenson (1942)
W. T. Thom, Jr. (1941)
C. W. Tomlinson (1941)
W. A. Ver Wiebe (1941)
John M. Vetter (1941)
T. E. Weirich (1942)
E. B. Wilson (1941)
Robert H. Wood (1941)
C. E. Yager (1941)

COMMITTEE FOR PUBLICATION

R. E. Rettger (1942), *chairman*, Sun Oil Company, Dallas, Texas

1940	1941	1942
Carl C. Addison	Thomas H. Allan	Charles G. Carlson
C. I. Alexander	T. C. Craig	James Terry Duce
George R. Downs	A. B. Gross	Coleman D. Hunter
Harold W. Hoots	Robert F. Imbt	Lewis W. MacNaughton
J. Harlan Johnson	J. T. Richards	Carleton D. Speed, Jr.
A. M. Lloyd	J. Marvin Weller	James L. Tatum
Joseph J. Maucini		Fred H. Wilcox
Graham B. Moody		

ASSOCIATION COMMITTEES

RESEARCH COMMITTEE

A. I. LEVORSEN (1942), *chairman*, 221 Woodward Boulevard, Tulsa, Oklahoma
M. G. CHENEY (1942), *vice-chairman*, Coleman, Texas

1940	1941	1942
HOWARD S. BRYANT	E. WAYNE GALLIGHER	N. WOOD BASS
LESLIE G. CASE	RALPH H. FASH	RONALD K. DEFORD
W. C. KRUMBEIN	W. S. W. KEW	WINTHROP P. HAYNES
EUGENE MCDERMOTT	JOHN C. MILLER	ROSS L. HEATON
C. V. MILLIKAN	D. PERRY OLCOTT	BELA HUBBARD
GAYLE SCOTT	BEN H. PARKER	PHILIP B. KING
E. H. SELLARDS	WENDELL P. RAND	T. E. WEIRICH
THERON WASSON	F. W. ROLSHAUSEN	
	F. M. VAN TUYL	

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

JOHN G. BARTRAM (1942), *chairman*, Stanolind Oil and Gas Company, Tulsa, Oklahoma

1940	1941	1942
PHILIP K. COCHRAN	MONROE G. CHENEY	JOHN E. ADAMS
GLENN S. DILLE	ROBERT H. DOTT	GENTRY KIDD
BENJAMIN F. HAKE	HAROLD N. HICKEY	HUGH D. MISER
R. M. KLEINPELL	MERLE C. ISRAELSKY	RAYMOND C. MOORE
C. W. TOMLINSON	WALTER K. LINK	

COMMITTEE ON APPLICATIONS OF GEOLOGY

CARROLL E. DOBBIN (1942), *chairman*, U. S. Geological Survey, 224 Custom House, Denver, Colorado

J. CLARENCE KARCHER (1942), *vice-chairman representing geophysics*, 406 Continental Building, Dallas, Texas

CAREY CRONEIS (1942), *vice-chairman representing paleontology*, Walker Museum, University of Chicago, Chicago, Illinois

1940	1941	1942
H. S. MCQUEEN	HAL P. BYBEE	LUTHER E. KENNEDY
B. B. WEATHERBY	HENRY C. CORTES	CHALMER J. ROY
	E. E. ROSAIRE	EARL A. TRAGER

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 5 (MAY, 1940), PP. 944-947, 1 FIG.

Memorial

FRANKLIN S. PROUT
(1889–1940)

Franklin S. Prout, "Shorty" to a host of friends in the industry, died at a hospital in San Antonio, Texas, on February 21, 1940, as a result of complications following an operation for appendicitis several days previously. At the time, he was out on the line of duty in the service of Cities Service Oil Company, his headquarters and the residence of himself and his surviving wife, Mrs. Dora Prout, being in Bartlesville, Oklahoma. His membership in this Association dates back to 1917 the year in which, under its original name, the organization was initiated.

Mr. Prout, a nephew of the late Colonel George W. Goethals of Panama Canal renown, was born in San Diego, California, December 5, 1889. He graduated from Stanford University, Department of Geology and Mining, in 1912. He spent the succeeding 2½ years in geological work in Venezuela and thereafter, save during army service, continued actively in oil and geological work in the Mid-Continent, Rocky Mountain, and eastern fields. During a portion of this time he joined with others in consulting activities. Since 1923 his work was with the Cities Service Company interests: first as geologist and then geologist in charge, in the Rocky Mountain division of Empire Gas and Fuel Company, 1924–1929; later as division geologist in New Mexico and Texas for the same company, 1930–1938; and since 1935 in like capacity with headquarters at Bartlesville for the Empire and the succeeding Cities Service Oil Company. His work in these assignments was such as to command the confidence and high regard of his associates and superiors in the organization; likewise, his ability in the geological field was widely recognized among geologists representing other companies. Many younger men, who at various times assisted him, were favored with the constructive interest which he displayed in their progress in geologic experience.

Mr. Prout's characteristic smile, with its reflection of genuine good-will and frank willingness to serve, will persist in the memories of his many friends.

W. L. Walker

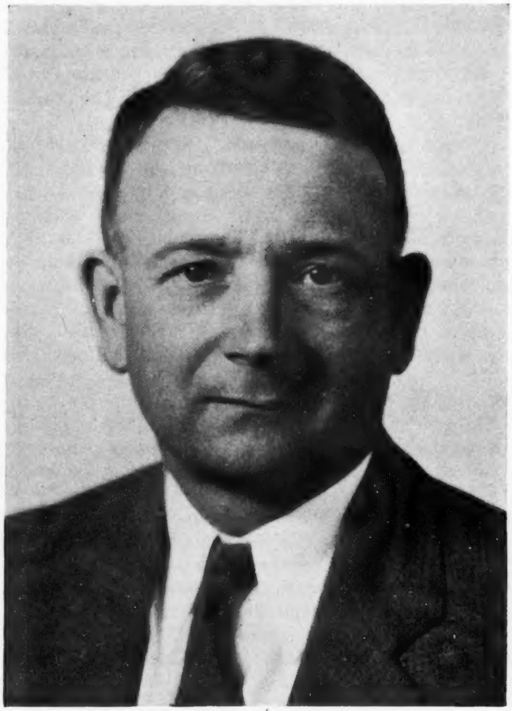
Los Angeles, California
March 20, 1940

WALTER WINTHROP SCOTT
(1893–1939)

On December 7, 1939, Walter Winthrop Scott, 46, chief petroleum engineer for the Humble Oil and Refining Company, died at Hermann Hospital, Houston, Texas, after a long period of illness.

He is survived by his wife, Mary Vandegaer Scott, two sons, Walter, Jr., and William C., one daughter, Betty Claire, all of Houston; his father, Charles C. Scott of Willits, California, three sisters, Mrs. R. C. J. Ritschel and Mrs. Ely Wonecott of Willits, California, and Mrs. J. J. Block of South Vallejo, California.

Mr. Scott was born in Santa Ana, California, May 14, 1893, and while he was still an infant the Scott family moved to Willits, California, which became "home." He received his grammar and high-school training in the schools of Willits. In the fall of 1912 he entered Stanford University and graduated in May, 1916, with a Bachelor of Arts degree in geology. As a student at Stanford he was entirely self-supporting, unusually resourceful, and earned all



WALTER WINTHROP SCOTT

monies necessary to complete his education. Summers from 1914 on were spent in the oil fields, working as a roughneck, and it was this association with the practical problems of oil production that gradually turned his interest from geology to a new profession, which is now known as petroleum engineering. While a senior student at Stanford, he was employed part time as a geological draftsman by the Shell Oil Company in the San Francisco office. In 1916, immediately after graduating from Stanford, he went to work as a geologist for the Oilfields, Limited, of Oilfields, California, and served with geological parties in mapping the Ventura and Pleyto anticlines.

On November 20, 1917, he resigned to go to work as a geologist for Pom-

eroy and Hamilton (Oil Issues) of Houston, Texas. His field work carried him to Many, Sabine Parish, Louisiana, where he met Miss Mary Vandegaer in 1918 and married her in September, 1920. When the Oil Issues Company began drilling operations, Mr. Scott was placed in charge. He became interested in the work of the United States Bureau of Mines and took the first civil service examination ever given under the title of "Oil Recovery Engineer."

Mr. Scott joined the Bureau of Mines in 1921 and after a short period of study in Washington, D. C., he was sent to the Bureau's Dallas, Texas, office. Much of his time was devoted to the study of the Haynesville oil field in Claiborne Parish, Louisiana, with special reference to the control of water and its exclusion from producing sands in order to increase the field's production, prevent waste, and lengthen the life of the field. The results of his work were gratifying.

In the spring of 1922, the Bureau sent him to Winnett, Montana, to attend to some land and lease matters. He was returned to Shreveport and then sent on a special mission to Mexico in connection with oil and gas studies for the Bureau.

In April, 1923, Mr. Scott went to Bakersfield, California, for the Bureau and while there he made an extensive study of rotary-drilling operations as conducted in that state. He often expressed a desire to arrange his notes in such a form that he could be the author of a bulletin for the Bureau of Mines on rotary drilling. He returned to Dallas, Texas, and was in charge of that office, making special arrangements for field studies in Texas, Louisiana, and Arkansas.

Early in 1924, Mr. Scott was sent to Casper, Wyoming, as an oil and gas supervisor. This assignment was short and on August 21, 1924, he was granted a one-year leave of absence to take a job as consulting engineer for the Sarawak Oil Company, Ltd. (Shell), in the Miri oil fields, Sarawak, Borneo, to help with drilling and water-control problems.

Returning to the United States in July, 1925, Mr. Scott again joined the Bureau of Mines and was sent to Bartlesville, Oklahoma, as superintendent of the station. Mr. Scott was a conservative and versatile worker with the Bureau; he handled many difficult assignments and suggested many engineering problems that subsequently became the subjects of bulletins for the Bureau by other writers. This association was admittedly one of the important phases of his life and he continued the association to the end.

On August 15, 1925, he resigned to accept a place with the Pure Oil Company at Tulsa, Oklahoma, in charge of their production engineering department. He served in their operations in Seminole, Oklahoma, and was recognized as an authority on the gas lift. He was transferred to the Texas producing division in connection with a number of deep wells that were being drilled by the Pure in the Texas Gulf Coast. On May, 1, 1928, he returned to Tulsa.

On May 31, 1928, he resigned to become chief petroleum engineer for the Humble Oil and Refining Company at Houston, Texas. Being a wonderful organizer, a firm believer in standardization and a keen judge of men, he soon perfected an efficient petroleum engineering department.

Mr. Scott joined the American Association of Petroleum Geologists in 1919. He was a member of the American Petroleum Institute and was especially active on its committees in matters pertaining to drilling operations. He also held membership in the American institute of Mining and Metallurgical

Engineers and the American Society of Mechanical Engineers. His hobbies were stamp collecting and flowers and whenever possible he made the famous "Azalea Trail." He was very fond of baseball and football, and played a good game of golf. He was a member of the River Oaks Country Club.

Walter Scott, affectionately known by his older friends as "Dago" and by others as "Scotty," entered Stanford spurred by the determination to go on with his friends in the quest for higher education. He earned his way by waiting on tables at a boarding club, operating college newspaper and laundry agencies, and any other jobs he could find. He was a fine young man, with excellent judgment and a quiet sense of humor which endeared him to all. Early in life he became a student in character analysis and continued this study to the end. Perhaps this, together with his rare ability to analyze and reduce problems he encountered to simple terms and to find a ready solution, was the most potent factor in his success. He was a natural leader who accomplished much with a minimum of effort. He was always self-effacing and never failed to give credit to those who worked with him. He was a man of simple tastes with the very highest moral standards. His family was always his first thought and he was a wonderful husband and father, a playmate and counselor to his children. The steps he followed to attain success in life offer a powerful example to what can be accomplished by determination and application. It can be truly said that all who knew him were the richer for the association.

D. P. CARLTON

HOUSTON, TEXAS
March 27, 1940

BIBLIOGRAPHY OF WORKS BY W. W. SCOTT

January, 1922. "The Haynesville Oil Field, Claiborne Parish, Louisiana," *Louisiana Department of Conservation Bull. B-11*, in coöperation with the *U. S. Bureau of Mines*. W. W. Scott and B. K. Stroud.

February, 1928. "Methods of Completing Wells in the Gulf Coast Fields." Paper presented at American Petroleum Institute meeting, Galveston, Texas.

May 3, 1929. "Modern Methods of Deep Well Drilling." Paper presented before the American Society of Civil Engineers, Dallas, Texas, April 24–25, 1929, *Oil Weekly*, Vol. 53, No. 7.

November, 1930. "Improvements in Production Practices." Paper presented at 11th annual meeting of the A.P.I., Chicago, Illinois.

November, 1931. "Improvements and Trends in Production Practices." Paper presented at 12th annual meeting of the A.P.I., Chicago, Illinois.

February, 1936. "The Trend of Oil Production and Petroleum Engineering." Paper presented at the University of Texas at the quarterly centennial celebration of the Division of Natural Resources of the University of Texas.

October, 1936. "Petroleum Engineering Education." Paper presented at the meeting of the American Institute of Mining and Metallurgical Engineers, Fort Worth, Texas.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 5 (MAY, 1940), PP. 948-952

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

E. L. DeGolyer, of Dallas, Texas, gave the address on March 15 at the dedication of Berthoud Hall, the new Geology-Geophysics Building at the Colorado School of Mines, Golden, Colorado. Following the Engineers' Day program, a reception was held by Francis M. Van Tuyl, head of the department of geology, C. A. Heiland, head of the department of geophysics, and J. Harlan Johnson, curator of the museum.

R. G. Hamilton, of the Schlumberger Well Surveying Corporation at Tulsa, Oklahoma, announces the location of the corporation's new offices at 729 National Bank of Tulsa Building.

Rollin Thomas Chamberlin, professor of geology at the University of Chicago, delivered the Grant Memorial lectures at Northwestern University, Evanston, Illinois: on April 17, "Earthquakes" (non-technical); April 15, "The Structure of the Middle Rocky Mountains"; April 17, "An Outline of the General Tectonic Features"; April 19, "Nature of Processes, Gravity Studies and Comparisons."

Hubert C. Igau, formerly with the Bishop Oil Company, is geologist for the Superior Oil Company of California at Houston, Texas.

W. Harlan Taylor has been appointed supervisor of the Gulf Coast district for the Petty Geophysical Engineering Company. His headquarters will be in Houston, Texas, and will be in direct charge of the company's seismic, gravity, and magnetic work. Prior to being placed in charge of the coastal division, Taylor served as supervisor for the company in Jackson, Mississippi.

J. M. Kirby, district geologist for the Rocky Mountain district of The California Company since 1937, with headquarters in Denver, Colorado, has been transferred to the San Francisco office of the Standard Oil Company of California, with permanent headquarters at 225 Bush Street.

E. E. Rosaire, of Houston, Texas, gave a paper on "Geochemical Prospecting" before the South Louisiana Geological Society at Lake Charles, March 19.

Henry A. Ley, president of the Association, discussed "Association Affairs" with the members of the South Louisiana Geological Society, March 25.

The Ardmore Geological Society, Ardmore, Oklahoma, has elected the following officers for the current year: president, W. M. Guthrey, The Texas Company; vice-president, Paul L. Bartram, Phillips Petroleum Company; secretary-treasurer, Tom L. Coleman, U. S. Geological Survey.

H. D. Thomas, associate professor of geology at the University of Wyoming, addressed the Rocky Mountain Association of Petroleum Geologists, Denver, Colorado, April 1, on "Pennsylvanian and Permian Stratigraphy of Eastern Wyoming."

JOHN B. SANSONE, resident engineer and geologist for the Union Pacific Railroad at Laramie, recently spoke before the geology department of the University of Wyoming on "Controlled Directional Drilling."

DON O. CHAPELL, geologist with the Transwestern Oil Company for the past 2 years in Illinois and Michigan, has been transferred to the company's main office at San Antonio, Texas.

The Alberta Society of Petroleum Geologists of Calgary, Alberta, Canada, has elected the following officers: president, J. B. WEBB; vice-president, E. H. HUNT; secretary-treasurer, R. G. PATERSON, 215 Sixth Avenue, West, Calgary; business manager, W. D. C. MACKENZIE.

The Panhandle Geological Society of Amarillo, Texas, elected new officers for the 1940–1941 term as follows: president, G. R. CARTER, Gulf Oil Corporation; vice-president, FRANK N. BLANCHARD, JR., Skelly Oil Company, Pampa; secretary-treasurer, H. H. HINSON, U. S. Bureau of Mines, Box 2250, Amarillo.

J. C. POOLE and A. M. COLE read a paper, "The Keeran, East Placedo, Placedo, and Heyser Fields of Victoria and Calhoun Counties, Texas," at a recent meeting of the Houston Geological Society.

H. D. HAND has moved from Iraan, Texas, to 1011 Clinton Avenue, Effingham, Illinois.

The annual meeting of the Independent Petroleum Association of America will be held at Dallas, Texas, Wednesday, Thursday, and Friday, October 16, 17, and 18, 1940.

MARTIN G. EGAN, geologist for the Shell Oil Company at Abilene, Texas, has resigned to enter consulting practice with WILLIAM E. BRUBECK at Mt. Carmel, Illinois.

T. E. WALL is chief geologist for the Allied Oil Production Company, with offices at 415 Gallatin, Vandalia, Illinois.

JAMES N. HOCKMAN has been transferred from Effingham, Illinois, to the Jackson, Mississippi, office of the Kingwood Oil Company as acting district geologist. ED SIBERTS will be in charge of the subsurface work in the Illinois office and CARL MAXEY will be returned from Mississippi to take care of the sample work in the Effingham, Illinois office.

PAUL WEAVER, chief geophysicist, Gulf Oil Corporation, spoke recently on "Origin of Large Salt Deposits, Including Those in Salt Domes" before the newly organized geological society of the University of Houston, of which PHILIP ALLEN, Gulf Oil Corporation, is president; E. J. MURDOCH, Shell Oil Company Inc., vice-president; JOHN KELLY, Ohio Oil Company, secretary, and RUSSELL CASEY, Woodley Petroleum Corporation, treasurer.

CARROLL E. DOBBIN, geologist with the U. S. Geological Survey, Denver, Colorado, spoke at a meeting of the Executives Club at the Sherman Hotel, Chicago, April 12 on "The Importance of Petroleum and Other Strategic Minerals in Present World Affairs."

W. H. TWENHOFEL, professor of geology at the University of Wisconsin, spoke on sedimentation before the South Texas Geological Society at Beeville, April 15.

B. B. WEATHERBY, president of the Geophysical Research Corporation, and vice-president of the Amerada Petroleum Corporation, Tulsa, Oklahoma, has succeeded the late C. K. FRANCIS, as co-chairman with GUSTAV EGLOFF, of the scientific committee of the International Petroleum Exposition, in charge of exhibits at the Hall of Science, May 18–25. He is assisted by KENT K. KIMBALL, consulting geologist of Tulsa.

The South Louisiana Geological Society held its regular monthly meeting, April 16, 7 P.M., in the Majestic Hotel, Lake Charles. URBAN B. HUGHES, consulting geologist of Laurel, Mississippi, gave a paper on "The Geology of Mississippi."

WALTER H. MADDOX, who has been in Netherlands, New Guinea, for the past 2½ years, has been transferred to the South Mediterranean Oil Fields Ltd., 33 Sharia El Malika, Cairo, Egypt.

J. ELMER THOMAS, petroleum analyst, who resides in Fort Worth, Texas, announces the removal of his office in Houston from 1010 Electric Building to 1434 Commerce Building, and the opening of New York offices at 150 Broadway, Suite 804, in association with Ralph E. Davis, Inc., consulting engineers for oil and gas properties. Thomas will devote his time principally to industrial reports and economic surveys.

Officers of the Stratigraphic Society of Tulsa for the year 1940–1941 are: president, JERRY E. UPP, Amerada Petroleum Corporation; vice-president, WENDELL S. JOHNS, The Texas Company; secretary-treasurer, FLOYD L. SWABB, Sun Oil Company.

The Northeastern Ohio Geological Society was organized at Warren, Ohio, March 16, with a membership of forty-three. Officers were elected as follows: president, LINN M. FARISH, Magnolia Petroleum Company, Box 629, Youngstown, Ohio; vice-president, ROLF ENGLEMAN, Carter Oil Company; secretary, D. R. DOBYNS, Magnolia Petroleum Company; treasurer, J. J. RUSSELL, JR., Sinclair Prairie Oil Company.

VERNER A. GILLES, assistant chief geologist of the Northern Pacific Railway Company, was appointed chief geologist, effective May 1 succeeding E. H. MACDONALD, retired under the pension rules of the company after 32 years of service. KARL A. E. BERG, assistant geologist, was appointed assistant chief geologist. MacDonald may be addressed at 134 Yellowstone Avenue, Billings, Montana.

HAROLD M. SMITH of the United States Bureau of Mines, Bartlesville, Oklahoma, talked on the subject, "Utilization of Natural Gas in the Production of Chemical Products," before the Tulsa Geological Society, May 6.

C. A. BAIRD writes from Copenhagen that the Danish American Prospecting Company is returning twenty Americans and their families to the United States, after temporarily suspending operations in Denmark. Baird and his family planned to travel across Germany to leave Italy on May 18.

R. G. SOHLBERG, of The California Company, has moved from Houston Texas, to 810 U. S. National Bank Building, Denver, Colorado.

A. E. FATH has moved from the Socony-Vacuum Oil Company at Cairo, Egypt, to the Vacuum Oil Company, S.A.E., Calle de Antonio Maura, 14 pral., Madrid, Spain.

M. M. KORNFELD, consulting geologist, Houston, Texas, lectured on "Local Cycles of Sedimentation in Gulf Coast Subsurface Correlations" at the Twenhofel conference on "Phases and Problems in Sedimentary Geology" at the Texas Agricultural and Mechanical College, College Station, Texas, April 20.

The Laramie Basin field trip of the Rocky Mountain Association of Petroleum Geologists, April 27–28, was arranged by geologists at the University of Wyoming and the staff of United States Bureau of Mines Petroleum Experimental Laboratory, Laramie, Wyoming. On April 27, S. H. KNIGHT, professor of geology and State geologist, gave a "chalk talk" on "The Late Cretaceous and Early Tertiary History of the Laramie Basin Region." On April 28 the itinerary included: Rogers Canyon (sandstone and limestone facies of Casper formation); Sand Creek (pre-Cambrian-Fountain contact); Red Mountain (marine Satanka fauna, Casper, Forrelle, *et cetera*).

The Pennsylvania Geologists will hold their annual conference, May 30–June 2, leaving Newton, New Jersey, 8:30 A.M., May 30. Places to be visited include Culvers Gap, McAfee Quarry, Franklin zinc deposits, Dover magnetite mines. The first day ends at Brunswick. On June 1 the coastal plain geology will be studied.

At the 297th meeting of the Washington Academy of Sciences, on March 21, at Washington, D. C., the award for scientific achievement in the physical sciences was bestowed upon W. H. BRADLEY, of the United States Geological Survey, for his contributions on the oil shale of the Green River formation of Wyoming.

J. B. HANLEY has been appointed assistant State geologist of Arkansas, at Little Rock.

FREDERICK SIMONDS, professor of geology at the University of Texas, was recently tendered a banquet in honor of his 50 years of teaching at the University.

ARTHUR IDDINGS is general manager of operations for the International Petroleum Company in Peru and Ecuador. He has moved his headquarters to Lima.

THOMAS J. FINNERTY has resigned as deputy and engineer with the California Real Estate Department and has opened an office for general consulting work in Los Angeles.

D. A. HOLM, 402 Goodrich Building, Phoenix, Arizona, has prepared a map of Arizona, 30×37 inches, on a base compiled by the State Land Department, showing the regions classified as probable petroliferous areas, some of the more significant structures including faults and folds, wells drilled in past years, and wells now drilling. Copies of the map may be ordered from Holm.

FIELD TRIPS

NORTH TEXAS GEOLOGICAL SOCIETY, MAY 25-26

The North Texas Geological Society will hold its annual field trip, May 25–26, covering outcrops of Canyon and Strawn age in the Brazos River and Trinity River valleys. M. G. Cheney is leader.

A pre-trip meeting will be held at 8:00 P.M., Friday, May 24, at the Driver Hotel, Graham, Texas when individuals experienced in the surface geology of the area will speak. The party will leave the Driver Hotel promptly at 8:00 A.M., Saturday, May 25, cross the Canyon section at three points in Young, Palo Pinto, Jack and Wise counties, and spend the night at Mineral Wells.

The trip on May 26 will cover the Strawn section in Parker County and at two points in Palo Pinto County.

Persons intending to take this trip should notify R. E. McPhail, Phillips Petroleum Company, Waggoner Building, Wichita Falls, Texas. If this notification can arrive on or before May 21, it will facilitate arrangements for the Society's field-trip committee.

L. E. PATTERSON, *vice-president*
NORTH TEXAS GEOLOGICAL SOCIETY

WEST TEXAS GEOLOGICAL SOCIETY, JUNE 8-9

The geologists of West Texas and Southeast New Mexico are sponsoring a two-day field trip in the Sacramento Mountains of New Mexico on the week-end of June 8 and 9, 1940. The exposed section along the west face of the mountains ranges from Cretaceous to pre-Cambrian. Attention will be directed toward the older Paleozoics that underlie the Permian basin on the east.

Geologists making the trip will have choice accommodations in camps at Alamogordo or at The Lodge at Cloudcroft. The party will meet on the mountains near High Rolls at 8 A.M., Saturday, June 8. Geologists arriving from a distance should arrange for transportation through the secretary of the West Texas Geological Society at Midland, Texas, who will also have charge of the distribution of road logs. If you are interested in making this trip or in securing a road log of the trip kindly get in touch with Fred F. Kotyza, Tide Water Associated Oil Company, Midland, Texas.

JOHN EMERY ADAMS, *president*
WEST TEXAS GEOLOGICAL SOCIETY

NORTHEASTERN OHIO GEOLOGICAL SOCIETY

The Northeastern Ohio Geological Society plans to visit Pennsylvanian and Permian sections exposed in the Pittsburgh basin and sections of older Paleozoic in New York. These trips can be planned to accommodate geologists from other areas. Tentative dates have been suggested for the last two week-ends in June or for over July 4. Time in the field will be 4–6 days. Anyone interested is urged to write Linn M. Farish, Box 629, Youngstown, Ohio, suggesting points of interest, suitable dates, and recommendations for duration of the trip.

LINN M. FARISH, *president*
NORTHEASTERN OHIO GEOLOGICAL SOCIETY

PROFESSIONAL DIRECTORY

OKLAHOMA

ELFRED BECK
Geologist

717 McBirney Bldg.
TULSA, OKLA.

1222-A Republic Natl.
Bank Bldg.
DALLAS, TEX.

GINTER LABORATORY
CORE ANALYSES
Permeability
Porosity
Reserves

R. L. GINTER
Owner

118 West Cameron, Tulsa

GEOCHEMICAL SERVICE CORP.
GEOLOGIC STANDARDS COMPANY

Soil Analysis—Core Analysis

JOHN W. MERRITT
321 South Detroit, Tulsa, Oklahoma

R. W. Laughlin L. D. Simmons

WELL ELEVATIONS

LAUGHLIN-SIMMONS & CO.
615 Oklahoma Building
TULSA OKLAHOMA

A. I. LEVORSEN

Petroleum Geologist

221 Woodward Boulevard
TULSA OKLAHOMA

G. H. WESTBY
Geologist and Geophysicist
Seismograph Service Corporation

Kennedy Building Tulsa, Oklahoma

PENNSYLVANIA

HUNTLEY & HUNTLEY
Petroleum Geologists
and Engineers

L. G. HUNTLEY
J. R. WYLIE, JR.
Grant Building, Pittsburgh, Pa.

TEXAS

JOSEPH L. ADLER
Geologist and Geophysicist

Consultant and Contractor in Geological and Geophysical Exploration

325 Esperson Bldg.
HOUSTON, TEXAS

MID-CONTINENT TORSION BALANCE SURVEYS
SEISMIC AND GRAVITY INTERPRETATIONS

KLAUS EXPLORATION COMPANY
H. KLAUS
Geologist and Geophysicist

115 South Jackson
Enid, Oklahoma

2223 15th Street
Lubbock, Texas

DIRECTORY OF GEOLOGICAL AND GEOPHYSICAL SOCIETIES

For Space Apply to A.A.P.G. Headquarters
Box 979, Tulsa, Oklahoma

COLORADO

ROCKY MOUNTAIN ASSOCIATION OF PETROLEUM GEOLOGISTS
DENVER, COLORADO

President - - - - - - - - Harold N. Hickey
810 U. S. National Bank Building
1st Vice-President - - - - - E. H. Stevens
Colorado School of Mines, Golden
2nd Vice-President - - - - - - - Ninetta Davis
224 U. S. Customs Building
Secretary-Treasurer - - - - - Dart Wantland
927 Humboldt Street

Dinner meetings, first and third Mondays of each month, 6:15 P.M., Auditorium Hotel.

KANSAS

KANSAS GEOLOGICAL SOCIETY
WICHITA, KANSAS

President - - - - - - - - - Anthony Folger
Gulf Petroleum Corporation
Vice-President - - - - - - Harold O. Smedley
Skelly Oil Company
Secretary-Treasurer - - - - - Lee H. Cornell
Stanolind Oil and Gas Company
Manager of Well Log Bureau - Harvel E. White

Regular Meetings: 7:30 P.M., Allis Hotel, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Building.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - - W. A. Clark
Mt. Pleasant
Vice-President - - - - - - - W. F. Brown
Mt. Pleasant
Secretary-Treasurer - - - - - C. H. Riggs
Michigan Geological Survey
21 Sheldon, N.E., Grand Rapids
Business Manager - - - - - S. G. Bergquist
Michigan State College, East Lansing

Meetings: Monthly dinner meetings rotating between Saginaw, Mt. Pleasant, and Lansing. Informal dress.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - Melville W. Fuller
Carter Oil Company, Mattoon
Vice-President - - - - - Maxwell B. Miller
The Texas Company, Mattoon
Secretary-Treasurer - - - James G. Mitchell
The Pure Oil Company, Clay City

Meetings will be announced.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY
SHREVEPORT, LOUISIANA

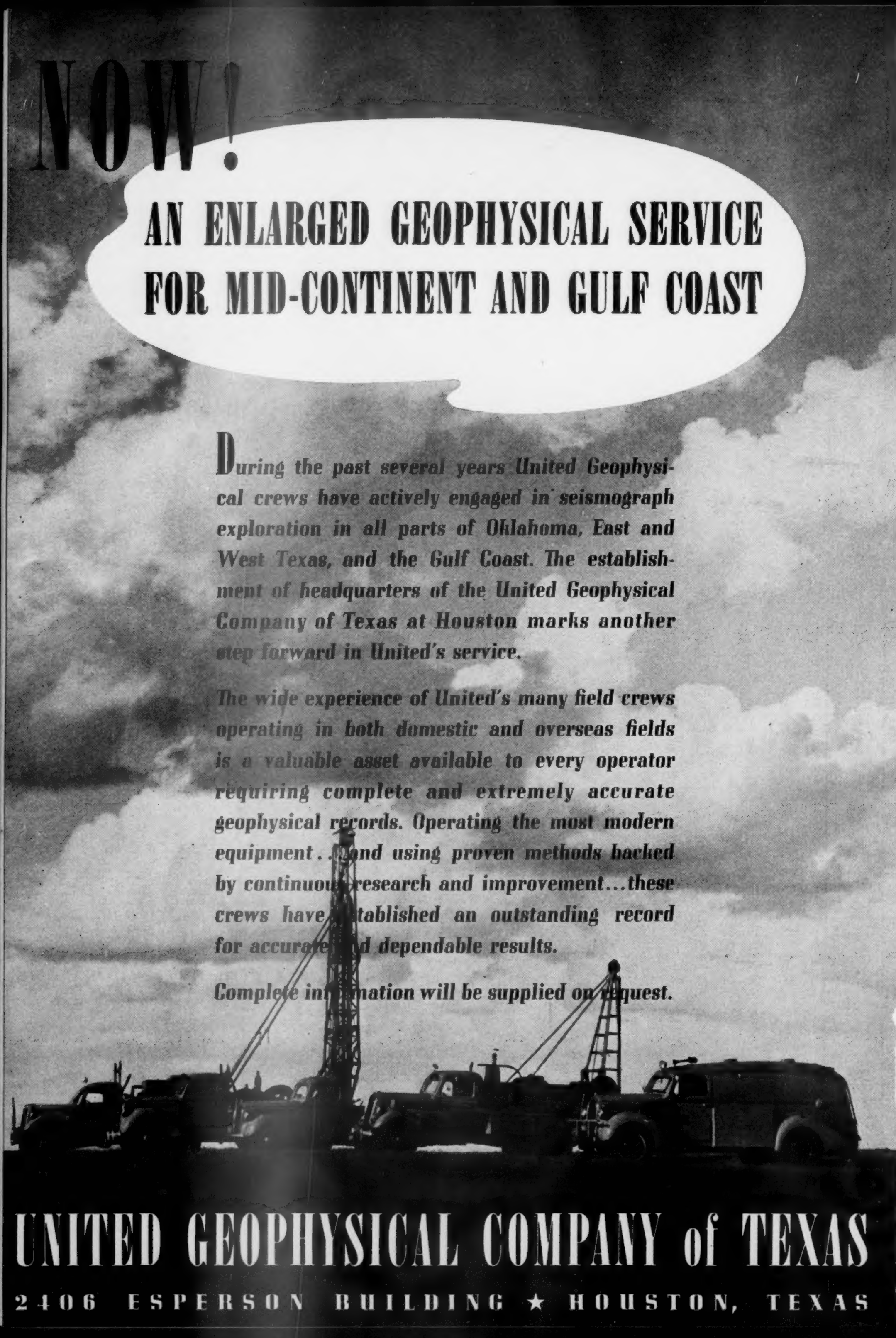
President - - - - - - - - - - E. F. Miller
Oliphant Oil Corp., 911 Commercial Bank Bldg.
Vice-President - - - - - - - - - J. D. Aimer
Arkansas Fuel Oil Company
Secretary-Treasurer - - - Weldon E. Cartwright
Tide Water Associated Oil Company
Historian - Anna Minkofsky, Shell Oil Co., Inc.

Meets the first Friday of every month, 7:30 P.M., Civil Courts Room, Caddo Parish Court House. Special dinner meetings by announcement.

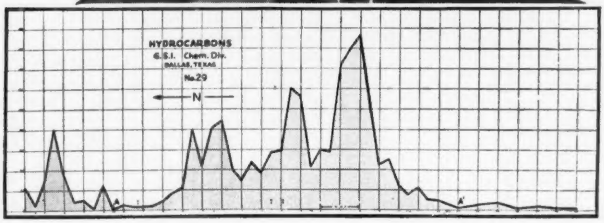
SOUTH LOUISIANA GEOLOGICAL SOCIETY
LAKE CHARLES, LOUISIANA

President - - - - - - - - - H. V. Tygrett
Atlantic Refining Company
Vice-President - - - - - - - - Coe Mills
Ohio Oil Company, Lafayette, Louisiana
Secretary - - - - - - - - E. M. Baysinger
Charles O. Noble
Treasurer - - - - - - - - - Baker Hoskins
Shell Oil Company, Inc.

Meetings: Luncheon 1st Wednesday at Noon (12:00) and business meeting third Tuesday of each month at 7.00 P.M. at the Majestic Hotel. Visiting geologists are welcome.


NOW!
AN ENLARGED GEOPHYSICAL SERVICE FOR MID-CONTINENT AND GULF COAST
During the past several years United Geophysical crews have actively engaged in seismograph exploration in all parts of Oklahoma, East and West Texas, and the Gulf Coast. The establishment of headquarters of the United Geophysical Company of Texas at Houston marks another step forward in United's service.
The wide experience of United's many field crews operating in both domestic and overseas fields is a valuable asset available to every operator requiring complete and extremely accurate geophysical records. Operating the most modern equipment . . . and using proven methods backed by continuous research and improvement...these crews have established an outstanding record for accurate and dependable results.
Complete information will be supplied on request.
UNITED GEOPHYSICAL COMPANY of TEXAS
2406 ESPERSON BUILDING ★ HOUSTON, TEXAS

CALL IN G.S.I.
—SOIL SURVEYS WILL GIVE TRUE EVALUATIONS OF LOW RELIEF STRUCTURES

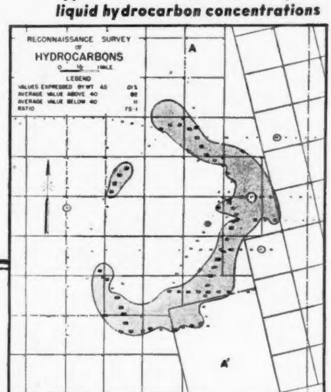


Low relief structures such as are found in some areas have assumed unexpected importance in the past year. Many a company has re-examined seismograph surveys in this new light.

While the seismograph indicates these marginal anomalies, a Soil Survey offers the only direct method of determining the presence of oil, and, if present, the boundaries of the field.

Call in G. S. I.—a few dollars invested in Soil Surveys may save you thousands in dry hole losses.

Typical cross section and map of liquid hydrocarbon concentrations



G. S. I.'s Pledge

... to do always the conscientious, thoroughly professional job for our clients that we would demand ourselves if we were employing a consulting company—to maintain G. S. I. leadership in design of instruments and technique of their operation, and to use only trustworthy men of proven ability for the important jobs of recording, interpretation, and analysis—to keep the results of all work in strictest confidence—and finally, to strive constantly to increase the percentage of discoveries and decrease exploration costs.

Eugene McDermott
PRESIDENT

GEOPHYSICAL SERVICE INC.

EUGENE McDERMOTT, President

SEISMOGRAPH SURVEYS
SOIL SURVEYS

DALLAS, TEXAS

Branch Offices: Houston, Texas – Jackson, Miss.
Los Angeles, Calif. • Tulsa, Okla.


for a CERTAIN
more ECONOMICAL
CORE
Use a
HUGHES
Type "J"
Core Bit!
HUGHES TOOL COMPANY • HOUSTON TEXAS